The Journal

OF THE

Royal United Service Institution.

VOL. IX. 1865. No. XXXVI.

LECTURE.

Friday, March 10th, 1865.

COLONEL SIR HENRY JAMES, R.E., F.R.S., Director Topographical Branch, War Office, in the Chair.

LENDY'S TOPOGRAPH.

By Captain A. F. LENDY, Director of the Practical Military College, Sunbury.

Captain LENDY: During the last few years it has frequently fallen to my lot to have to teach surveying to officers who could spare but a short time for study. Although the prismatic compass is a very simple instrument, yet the construction of scales, and the use of the protractor, were found such a difficulty by those whose mathematical knowledge was very limited, that I became imbued with the idea that an instrument that could be used more expeditiously was much wanted in the Service. Important improvements have been introduced by the French in the construction of their topographical instruments, and I have combined in the Topograph all the improvements likely to be serviceable. A plane table of Major Fèvre has been introduced in the French service to survey either on foot or on horseback, and it is now used by staff officers. Another instrument, the "Echelle-rapporteur" of Lieutenant Trinquier, is generally adopted by regimental officers, on account of the rapidity with which the prismatic compass can be used for military sketching. In this country Major Griffith, R.A., Professor of Military Sciences at King's College, has endeavoured to combine the clinometer with the prismatic compass. Others have imagined portable levels; but in no instrument that I know have all these properties of the plane table, prismatic compass, clinometer and level been combined.

Before explaining the use of the Topograph, a few words on military surveying will not be found out of place.

Military surveying differs essentially from other kinds of surveying, and requires methods of its own. Rapidity of execution and simplicity of means are essential qualities which must be secured even at the expense of great accuracy of measurement.

When a tract of land is to be surveyed, every one here present knows that the first thing to be done is to establish the triangulation. We imagine all the chief points, such as steeples, crossing of roads, remarkable trees, &c., united by straight lines, which form a sort of netting between the meshes of which all the details are contained.

The plan of these triangles or "canvass" may be made in several ways. The ordinary method consists in measuring one side or base, as it is called, and in taking the angles with a theodolite. Trigonometry enables us with these data to calculate the whole of the triangles.

In military surveying, however, we need no such calculation. We measure the base, and construct at once the triangles, either by means of the plane table, or by protracting the azimuths given by the prismatic compass.

The theodolite is an instrument which we ought not to employ. It is heavy and cumbersome, and the accuracy with which it gives the angles is of no avail in a military survey. We cannot protract the angles within a few minutes, therefore the seconds are useless to us; and even if we could protract angles within a minute, the effects of the atmosphere on the paper would soon render our trouble of no avail.

I do not mean to say that we should not endeavour to be as exact as we possibly can; far from it. Small errors accumulating, soon render a correct survey impossible, but I mean to say that we should not aim to extreme accuracy. The scale to which we draw is in itself a source of error. Admitting that our eyes cannot appreciate the $\frac{1}{100}$th of an inch, and this is not far from the truth, it follows that on a plan on the scale of four inches to the mile there is an unavoidable error in reading of 5 yards. We should not, therefore, attempt to represent two or three yards.

The prismatic compass is the military instrument, "par excellence;" but the plane table is by no means to be despised, although it seems to have entirely disappeared in England. Circumstances, nevertheless, occur when it is extremely useful, and so thought the late Mr. Burr, when he put it into the hands of the Sandhurst cadets. Granting the objections made to the unwieldy table of old, let us remark that we cannot dispense with a drawing board of some kind. Now, if this board can be turned into a plane table, it will possess the advantage of rendering some service to those who do not despise a triangulation made with a goniograph.

The triangulation completed, we proceed to fill in the details, and here pacing is advantageously employed

In the surveys executed by civil engineers, and even by most military men, a field-book is employed to enter all the dimensions, which are afterwards plotted at home. There are several objections to this

mode. Errors are more likely to creep in when we have to transfer the contents of the field-book to paper, than when we plot on the ground, where a mistake is soon perceived and soon rectified. Again, the field-book may be mislaid, and all the trouble gone through lost. In active service especially the information needed by a General, and for which a reconnaissance is made, may be wanted at a moment's notice, and when the plotting is made on the ground there is no delay.

The next operation is levelling. Here, again, we need not know the true altitudes; we only require the relative heights. The clinometer will answer the purpose, and the more simple it is the better. Should it be required to draw horizontal contours, a level is necessary, and if our clinometer permits us to trace these contours at once without making entries in a field-book, we shall have secured rapidity of execution.

To recapitulate, we require for a military survey—

1. A drawing-board.
2. A prismatic compass, or plane table.
3. A protractor.
4. A scale and a pair of compasses.
5. A clinometer.
6. A level.

The Topograph combines all these. It may be used—

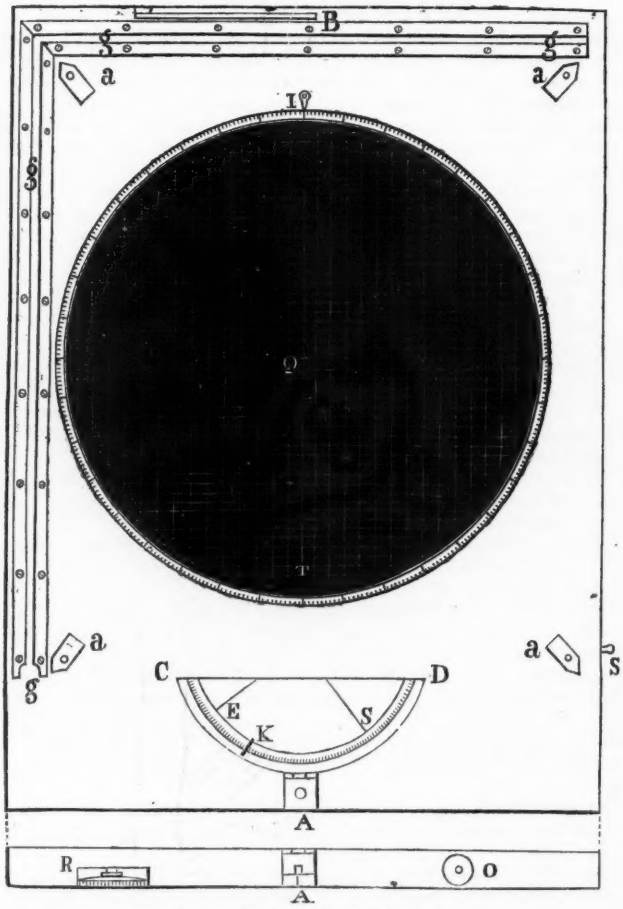
1. As a prismatic compass alone.
2. As a plane table alone, with its sight ruler.
3. As a plane table and a compass (déclinatoire of the French) combined, to facilitate the finding of stations.
4. As a clinometer, to obtain angles of elevation or depression, to find the difference of altitude of two stations.
5. As a level to lay down contours.

It possesses that great advantage that it may be employed without any alteration, simultaneously or successively, as a plane table and a compass in the same survey, when we pass from undulating ground to open country, and *vice versâ*. It may be used on horseback or on foot, and in the latter case a tripod stand renders it a very precise instrument. For ordinary purposes, however, no stand is required. In all cases we need no scales, no pair of compasses and no protractor, the instrument itself protracting the angles, and laying down distances to scale.

The instrument is light and scarcely weighs 15 ounces, less than an ordinary box sextant, and its price is four times less than that of the various instruments which it replaces.

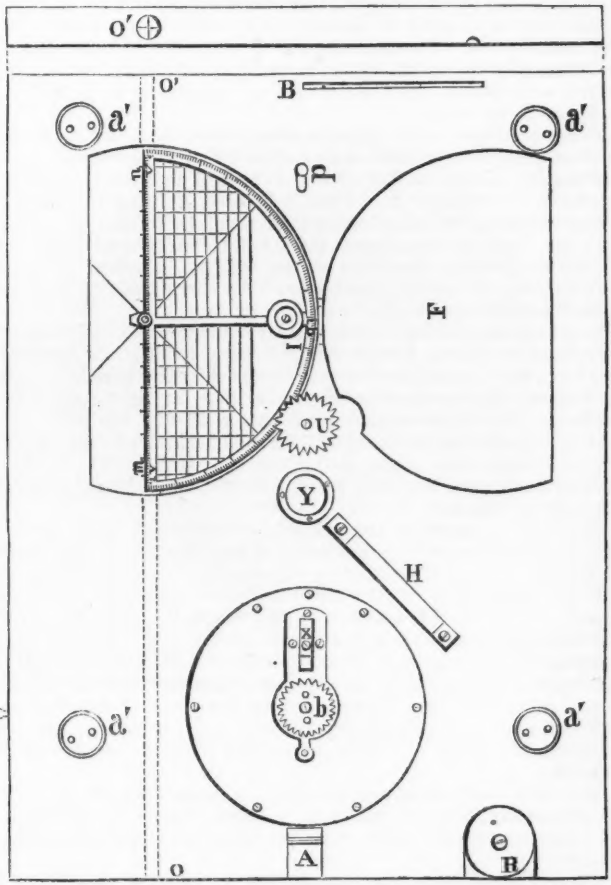
Finally, it will enable any one, however unacquainted he may be with mathematics, to become in a few minutes capable of making a military sketch. Altogether, for those who have surveys to make, and a great deal of ground to survey, the instrument would save them very nearly half the time now necessary.

PLAN OF THE UPPER SURFACE.



a, a, a, a. Grapples, serving to secure the Paper.
A. Prism.
B. Sight Vane.
C D. Prismatic Compass.
S. Spring, checking the vibrations of the Card.
Q T. Protractor, carrying the Scales.
I. Fixed Index.
g, g, g. Grooves, in which the head of the Sight Ruler is inserted when using the Plane Table.

PLAN OF THE LOWER SURFACE.



a', a', a', a'. Springs, serving to loosen the Grapples.
H. Leather Handle, by means of which the Topograph is carried.
Y. Hole and Female Screw, serving to fix the Topograph on a Tripod.
X. Button, which fastens the Card when the Prismatic Compass is not used.
b. Screw, Serving to fix the Index *K* in any required position.
U. Screw, moving the Protractor.
R. Sight Ruler, secured in its scabbard.
l, m, n. Clinometer.
v, v'. Pins of the Clinometer.
p. Spring, which fastens the moveable circle.
q. Index or Clinometer.
F. Lid of Clinometer when opened for use.
O O'. Level.

The following are the directions for using the Topograph:-

Paper.—The paper used with this instrument should be transparent. A thin paper does not bear India-rubber, suffers much from moisture, and is easily torn. The best material is what is sold under the name of Tracing Paper No. 12. It is a transparent fabric, linen or calico, coated with paper. It stands rubbing, cannot be torn, and is not easily spoilt by rain.

Fixing the Paper.—The paper is stretched on the board by means of the four grapples *a*, which are kept tight by strong springs.

Prismatic Compass.—The instrument is held in the left hand by the handle *H*. The prism *A* and the sight vane *B* being raised to their proper positions, we take bearings as usual by turning the left hand until the object is seen through the slit in coincidence with the thread of the vane. The vibrations of the card are checked by pressing on the spring *S*, and the graduation that corresponds to the thread, gives the required azimuth.

To protract the Bearings.—The circular protractor attached to the upper surface of the board has its circumference divided into 360 degrees, and bears two graduations—one in black, the other in red. The circle is ruled over by two systems of parallel lines at right angles to one another. The lines parallel to diameter 90–270 are red, and at intervals representing 20 paces on the scale of 8 inches to the mile, every fifth line being made thicker to facilitate the reading. The black lines, parallel to diameter 360–180, are at intervals, representing 20 paces on the scale of 6 inches.

To trace a direction—the azimuth of which has been found to be 40°, for instance—we turn the screw *U* with the thumb and forefinger of the left hand until the black graduation 40 comes under the index *I*. All the black lines of the circle are now parallel to the direction required, the line *Q* I representing the magnetic meridian. To draw the direction, we trace with the pencil the black line passing through the point of station. The distance paced in that direction—120 paces for instance—is laid down by marking across six intervals of the red lines. Should we require a survey on the scale of 6 inches to the mile, we protract the bearings with the red graduation, and lay the distances along the red lines across the requisite number of black intervals.

Any Scales.—By assuming the divisions to represent 40 or 10 paces we obtain the additional scales of 3 inches, 4 inches, 12 inches, and 16 inches to the mile. The protractor being moveable, other scales can be used.

Plane Table.—When the Topograph is to be used as a plane table we still hold it in the left hand. The sight ruler is removed from its scabbard *R R*, and is inserted in the grooves *g g*. It is thus prevented from falling, a disposition readily appreciated by those who have to survey on horseback. When the ruler has been turned to its proper position it is secured by its screw, and the required direction is then easily drawn. Distances are laid down as before by means of the protractor.

Plane Table and Compass.—When using the plane table, stations are

easily found with the assistance of the compass. For that purpose the opening *C D* corresponds to an angle of more than 90 degrees; in whatever position, therefore, the instrument may be turned, one of the four radii, N., E., S., W., must fall within that opening, and an index K, moveable by the screw *b*, can be placed exactly opposite to that radius.

In all the above cases the instrument can be used with a tripod, whenever great precision is necessary.

Clinometer.—The clinometer consists of two semi-circles, a fixed one and a moveable one. The fixed semi-circle is pasted to the board with its diameter exactly parallel to *A B;* its surface is divided into zones of equal width by vertical lines graduated from the centre to the right and left. A second series of equidistant lines are drawn parallel to the diameter, and are graduated downwards.

The moveable semi-circle is made of brass. Its diameter is divided into parts corresponding exactly to those of the fixed one, and its circumference is divided into 90 degrees on each quadrant. The moveable diameter carries two small pins projecting outwards; and on the prolongation of the fixed line, we find two holes *o o'* right through the length of the board, in exact parallelism with *A B.*

To find a Level Line.—To obtain a horizontal line, hold the instrument vertically with the left hand, and look through the hole *o;* when the hole *o'* and the two pins of the moveable diameter come in line, the direction *o o'* is horizontal.

Angles of Elevation.—To take angles of elevation or depression, hold the instrument in the same manner, and look through the hole *o* until the object appears in a line with the hair of hole *o'*, pressing on the spring *p* which fastens the brass protractor. The angle required is marked by the index *q*.

Vertical Distances.—It is readily seen that such a triangle as *o b a* is similar to *O M N.* If we assume *o b* to represent the horizontal distance between the two points *O* and *N*, the vertical *b a* will represent the difference of altitude, the value of which is marked on the margin. If, for instance, the angle of elevation is 25°, and the horizontal distance

furnished by the plan 290 yards, the difference of altitude is obtained by taking division 29 of the fixed diameter, and following its vertical

until it intersects the moveable diameter. The horizontal passing through the point of intersection is $13\frac{1}{2}$, and therefore the difference required is 135 yards.

Reduction of Distances to the Horizon.—To reduce to the horizon a distance measured along a slope, turn the brass semicircle until the index points to the angle of elevation. The divisions of its diameter represent the distances actually measured, whilst the verticals passing through these divisions point, on the fixed diameter, to their horizontal projections. Thus, if the distance measured is 530 yards, and the angle of elevation 20°, the horizontal distance is 498 yards.

Contouring.—Let us suppose that in a survey, contours are wanted 10 feet vertically apart. We begin, as in the ordinary process, by tracing one contour on the ground and then on the paper, an operation which the level *o o'* will render easy. We then station on that contour, at some convenient point belonging to a ridge, a thalweg, or a regular slope, and take the angle of elevation or depression. The parallel 10 intersects the moveable diameter, and the vertical passing through this point of intersection gives, on the fixed diameter, the horizontal distance between the contours. If the angle of depression is 17°, the contours along the uniform slope should be 33 feet apart on the plan.

The CHAIRMAN: I have no doubt you are gratified with the description of this instrument, which has many good points combined in it. You will, I am sure, agree with me that the thanks of this meeting are due to Captain Lendy.

LECTURE.

Friday, March 24th, 1865.

REAR-ADMIRAL SIR F. E. NICOLSON, Bart., C.B., in the Chair.

ON THE COMPARATIVE MERITS OF SMOOTH-BORE AND RIFLE ORDNANCE WHEN EMPLOYED AT SEA, AND ON THE PROPER ARMAMENT FOR SHIPS OF WAR.

By Commander B. SHARPE, R.N.

WHEN erroneous views on a professional subject have obtained possession of the public mind it is a difficult task to combat them in such a manner as will lead to a conviction of their unsoundness; but the task is more difficult when the same subject can be applied to two distinct professions, for when found adapted to the one profession it is generally deemed equally applicable to the other.

In the questions we are about to consider, this double application has exercised an adverse influence, the requirements for guns on shore having induced the belief that those for the Navy must be similar, and that the same means would provide for them.

It is perfectly true that such general laws as those which govern the motions of bodies through the air (being applicable to both services) have afforded a common basis for the education of the Officers and men, but with this, all analogy between the gunnery of the two professions ceases, for on shore we find both the gun platform and object fired at in a state of rest, while at sea both are in constant, and at times violent motion.

A distinguished Admiral lately observed to me that gunnery at sea differed as widely from gunnery on shore as did shooting flying from shooting with a rest, but he even understated the case, for a sportsman on shore on an immovable platform has full command of his weapon, whereas a sailor at sea has not only his platform in motion, but finds his gun *forcéd* to partake of the inclination and movements of the ship. The difficulty attending a sailor's arm is, therefore, infinitely greater than that of the sportsman.

Naval gunnery may, indeed, be considered a distinct science; and the principal reason why so many eminent men have failed in their attempts to improve the armament of the Navy, is to be found in their want of a sufficient acquaintance with the peculiar exigencies of the sea-service.

It is universally admitted that in every profession and trade a special knowledge is required; how much more, then, must a naval knowledge be requisite in naval matters, when even a seaman's experience to be of any value must date from his boyhood? I shall not, therefore, be arrogating too much when pointing to the necessity for viewing naval questions in an exclusively naval aspect, and if this had always been the case, it is probable that many of the fundamental errors which now exercise a baneful influence in naval gunnery would never have occurred. Take the sights for instance (on which accuracy of aim is mainly dependent), and it will be found that so faulty are they in principle when employed on a moveable platform that they originate a distinct error absolutely fatal to a correct aim, and yet their projectors were persons highly eminent in their several positions, such as Sir W. Congreve, General Millar, Sir W. Armstrong, and others, but who, unfortunately did not possess that special naval knowledge by which such grave errors might have been avoided.

There are, again, gun carriages and slides, which, however adapted for batteries on shore, are so unsuited for employment at sea as at times to endanger the very safety of the vessel. I might, for example, point to the heavy bow and stern guns in many of the steamers, which guns, with a rolling motion, cannot even be cast loose without a strong probability of their turning over, and a gun of some five tons weight falling to leeward with a lurch would scarcely fail to start a vessel's timbers.

In the comparisons I am about to institute I propose confining myself to an *exclusively sea view* of the various points as they arise, and as my observations are founded on a personal experience of many years while in charge of the gunnery department on board several of Her Majesty's ships, they may possibly help to place these important questions in a more satisfactory position.

I will now point out the principal points of difference between smooth-bore and rifle guns as they affect the practice at sea, so that their relative advantages or disadvantages may be accurately weighed.

The cause which, in the first instance, led to the invention of rifles will lead us to these points of difference, and enable us to judge how far the invention has been successful in its immediate object, and whether that object still exists, and also whether the change has not brought with it evils far more serious than those it was intended to remove.

The invention of rifles, as many of us are aware, did not arise from any defects in the form of the smooth-bore gun, but entirely from the faulty manufacture of the shot then in use, and which it was intended to combat; the deviation of the shot from a direct course being

attributed to superficial inequalities on which the air unequally acted, to obviate which a spiral grooving was cut in the bore of the gun, so that a shot in its passage out might acquire a rotary motion on an axis coinciding with its line of flight, and so expose its superficial inequalities on all sides in rapid succession.

Sir Howard Douglas, the eminent writer on gunnery, when describing the principle of the rifle, informs us that a properly made round ball may be projected from a smooth-bore gun with as much accuracy as from a rifle, but his exact words, which will be found at page 99 of his work, will best convey his meaning. They are as follows :—

" The rifle principle is a contrivance to reduce the errors arising " from the unequal action of resistance on any superficial inequalities " in the ball, by giving it a rapid rotation perpendicular to the axis of " projection; but it is found that a ball of uniform consistency or " solidity, smooth and perfectly spherical in its shape, may be pro- " jected from a plain barrel with as much accuracy as from a rifle."

This quotation (and the opinion of Sir Howard Douglas will probably have some weight) supports my assertion that the invention of the rifle arose from imperfections of the shot, and that with properly made shot the smooth-bore is as accurate as the rifle. The utility of the rifle will, therefore, naturally cease with the removal of the originating cause, and as balls perfectly spherical can now be produced in any quantities, the necessity for the rifle no longer exists.

It is much to be regretted that the immediate object of the rifle has seldom been kept sufficiently in view, as some of the high talent which has been devoted to the rifle and its grooving might have been better employed in improving the smooth-bore and its shot, and then the introduction of rifle guns on board ship very probably would never have been attempted.

The quotation from Sir Howard Douglas has shown that with balls perfectly spherical, a rotary motion is unnecessary. I will now endeavour to show that on board a ship at sea, a rotary motion in the shot *is absolutely fatal to a correct aim.*

It is a well known fact that, according to the direction of the grooving, a rifle-ball will deviate either to the right or left hand, and also that the deviation of the rifle-ball may be approximately shown by such verniers as are attached to the sights supplied with the Armstrong guns to the Navy; but it may not be so well known that for the verniers to act correctly the guns must be kept perfectly upright, with the tangent sights working in a perpendicular, and the verniers in a horizontal plane, which, on board a ship heeling over, is, with these sights and verniers, impossible, as the sights will then partake of the same lateral inclination as the guns, and throw the verniers out of their proper horizontal position, and the verniers will then loose their power of marking the deviation of the shot, and what is worse, will interfere with the gun's elevation, increasing or diminishing it *according to the tack of the ship*, such increase or diminution depending on the extent of the ship's inclination, and as motion and inclination are the normal condition of a ship at sea, it is evident that until some better means

for correcting the error have been devised, the rifle, when compared with the smooth-bore, must, for sea purposes, be considered as retaining all the serious disadvantages of this error uncorrected.

We will now examine the effect of the rifle error on the gun practice at sea, and will suppose a ship to be on the starboard tack engaging with her weather guns, and the wind abeam blowing fresh and greatly influencing the flight of the shot, and that it does so affect the shot there will, I conclude, be no dispute. I may, indeed, mention that I observed in the "Times" of January 20th, in reference to a competition of volunteers, that "in one squad the rifle had to be aimed 38 feet off the bull's-eye, *on account of the wind.*"

If the weather guns be now "extreme trained to the right," the wind blowing across the range will throw the shot to the right of their proper course, and if "extreme trained to the left," in like manner to the left; or in other words, the tendency of the wind will be to throw the shot to leeward of the object aimed at; this a sailor can well understand, and he will apply the best remedy in his power by pointing as much to windward of his object as habit (and habit alone) tells him, the then strength of the wind requires.

In this there is no difficulty, for a practised sailor feels, rather than calculates, the strength of the wind, and knows intuitively the required allowance; but how will a sailor act when an allowance for the rifle error has to be *added* to the wind's allowance when firing before the beam, and *subtracted* from it when firing abaft, or *vice versâ*, according to the direction of the grooving? He will find it an impracticable task to attempt. The error of the rifle has, therefore, yet to be surmounted, and unless this can be done in a practical manner, the employment of rifle guns at sea can no longer be supported on the ground of greater accuracy.

Another serious result of the rotary motion, which I must not omit to mention, is the deflection of the shot to the right or left after striking the water, and which, in a fleet action, would prove nearly as dangerous to friends as to foes.

Ricochet firing is also prevented by the rotary motion of the ball, and this kind of firing is invaluable against the attacks of gun-boats, and cannot lightly be sacrificed to any merely problematical advantage in another direction; but all firing at a low angle, when the shot grazes the water before striking the object, will have its accuracy affected, indeed destroyed, if a rotary motion be given the shot.

Another great hindrance to correct practice at sea with rifle guns is the greater length of time which elapses between pulling the trigger and the shot quitting the muzzle of the gun, and which is chiefly to be attributed to the detention of the ball by the rifle grooving, and to the slow-burning powder commonly used with rifle guns, the two causing the lapse of a sensible interval of time.

This loss of time will probably be deemed of little moment by Officers of Artillery, who are accustomed to have both the gun and the object fired at on an immoveable platform, but in the Navy, where both the gun and the object are in constant motion, the case is widely different, as I will endeavour to show.

In pointing guns at sea it is the usual practice to lay them in such a position that the motion of the vessel may cause their muzzles to pass as much above as below the object aimed at, the triggers being pulled when the object appears in a line with the sights; the muzzles of the guns are, consequently, at the time of firing, moving rapidly past the object at the quickest period of the vessel's roll, and the shot, to be successful, must, therefore, quit the muzzle of the gun as nearly simultaneously as possible with the pulling of the trigger; for, should the gun hang fire, or the shot from any cause be delayed in passing along the bore, the muzzle of the gun, in continuing its unbroken movement, will pass either above or below the object, according as the firing may be with a rising or falling motion, and so cause the shot to be thrown in a direction altogether different from that intended when the trigger-line was pulled, in fact, much higher or lower than was desired, the error increasing with the length of time which elapses between the instant of firing and of the shot's quitting the gun, and with the rapidity of the roll, and when we observe how wide a difference in the length of range is caused by the smallest alteration in the tangent scale, we may form some conception of how completely a shot will be thrown away by the slightest detention after pulling the trigger.

But with respect to the ball being detained by the friction of the grooves, or by any sudden grip or obstruction during its passage along the bore, I am not aware of anything more directly conducive to the bursting of a gun; and I much fear that this, and the action of the air in the neighbourhood of the charge, has never yet received sufficient attention, or many of the present views would be considerably modified.

The effect of only a very slight obstruction may be seen by the immediate bulging or bursting of the barrel in the vicinity of the ball, which takes place if a musket be fired while the ball is merely rolling down the barrel; or place the muzzle of the gun in so yielding a substance as water, or stop up the muzzle with soft clay, and the gun will probably burst at the muzzle; but I need not go further, it being well known that the action of the powder on the gun itself is always greatest between the charge and the ball.

At the same time, and which is very important, the action is not equal throughout this space, but is always greatest at the obstruction, as shown by the rolling ball; the metal of the barrel bulging out as if the shot itself had expanded and so forced out the gun; this arises from the air between the powder and obstruction having suddenly accumulated at the latter by the advancing gases, and becoming there intensely elastic, spreads out on all sides; but from all this danger of bursting, be it observed, the smooth bore is exempt, and is, therefore, capable of bearing far heavier proportionate charges than the rifle gun.

A low rate of velocity in the projectile is another source of inaccuracy in the rifle, for objects at sea being generally in motion are not likely to remain sufficiently long in the same position for the shot to reach them.

Amongst other causes of detention, the projections and roughness on

the surface of a rifle-ball will greatly retard its flight, the resistance of the air, to which must be calculated, not simply from the extent of surface the projections oppose to the air, but by the diameter of a circle which shall include all the projections, the rapid revolution of these projections causing the same resistance to the air as would a circular solid having a diameter equal to this circle; it is, in fact, the principle of the rifle over again, which, presenting the protrusions on all sides in rapid succession supplies a continuous obstruction equivalent to a circular solid.

A very small projection will consequently make a very considerable difference, circles being to each other as their diameters squared, and it is necessary to double the projection to supply the diameter required for instituting a comparison; the increased resistance experienced by rifle beyond smooth-bore shot of the same diameter will, therefore, be very considerable, and be equal to the area of the circular ring generated by the revolution of the projections; for, if a projection on the surface of the shot offers a certain amount of resistance at any one point, it will offer the same resistance at all other points at which it may successively appear, and when the movement from point to point is sufficiently rapid, the resistances will blend together and form a circle of resistance equal, as I have just observed, to the circular solid the projection apparently forms while revolving.

A low rate of velocity, from its preventing the shot penetrating, is, moreover, quite unsuited to naval warfare, where the highest attainable velocity is required.

Many persons are misled by the plausible, but incorrect notion that a given momentum, will, under all circumstances, accomplish the same end, that as mass multiplied by velocity equals momentum, the relative position of the two multipliers need not be considered; so that a 10 lb. ball, projected with a velocity of 1,600 feet in a second, will have the same *penetrating* effect as a weight of 1,600 lbs. moving at the rate of only 10 feet in a second, or if this example be insufficient to expose the fallacy of the notion, we have only to increase the weight and reduce the velocity still more, to make it apparent.

It is, however, quite a mistake to confound the momentum of a body with its ability to penetrate a given substance; penetration requires the greatest concentration of weight under the smallest diameter, in fact, the smallest area of opposing surface in the projectile, and (but most important of all) the highest attainable velocity, which latter will enable a shot to pass onwards, bearing with it a portion of the penetrated substance equal to its own diameter, before there can be a reaction among the contiguous particles of the penetrated body to impede its progress, and before it can impart any portion of its own force to the surrounding substance to become dissipated in waves of vibration, as will happen whenever the projectile strikes with a low degree of velocity.

The highest attainable velocity is now so absolutely essential in naval warfare, that I feel it difficult to express in terms sufficiently strong how urgently it is required; it should be striven for by every available means, and everything in the guns conducive to it should

be developed to the utmost; a sufficiently high velocity will carry a thin shell through a thick iron plate, whereas a low velocity will cause the shell to break up in fragments when brought in contact with even a thin plating; but on other grounds besides penetration, the highest velocity is of paramount importance in naval warfare, for the accuracy of the practice is greatly increased by it, and the area of the shot's most efficient performances is equally extended by it.

We know that gravity acts equally on similar bodies, so that a shot projected horizontally at the rate of 2,000 feet in a second, will descend to a common plane in the same time as a similar shot dropped from the muzzle of the gun at the instant of firing. The law of gravity is inexorable, and whatever may be their horizontal velocities, similar shot will descend through the same spaces in the same times; thus gravity becomes literally a question of time, and the longest range in a given time is therefore the essential point, and the greater the velocity the longer will be the distance a shot can be propelled in a given time, and the slighter will be the curvature of the shot's path, and the more accurate the practice.

This curvature of the shot's path is entirely due to an insufficient velocity, which requires the muzzle of the gun to be raised above the object to prolong the time of the shot's flight; to fire a shot at an elevation is only taking the stream of gravity at a higher point, and is but a rude method of gaining time at the expense of accuracy, for the curve described by the shot will militate most seriously against the shot's striking the object; but increase the velocity of the shot, and it will reach the object by a shorter and more direct path, and from these combined causes in a less space of time and with greater accuracy. The greater the velocity of the shot, the smaller will be the elevation required by the gun for neutralizing the action of gravity, and the more direct will be the shot's path, and the slower will be the descent, *for gravity acts in spaces proportional to the times squared.*

Having said this much on high velocities, I may add that I do not know a greater fallacy in naval warfare than low velocities and wide diameters in projectiles intended to penetrate armour-plated ships.

But as regards the diameter of the projectile, the enormous increase of resistance which accompanies every slight addition to it appears not to have received the full consideration its importance requires; a diameter of eight inches meets with four times the resistance that a circle of half its diameter encounters, and a diameter of sixteen inches four times that of one of eight, the resistance increasing as the squares of the diameters, and which entails a corresponding addition to the propelling force or powder, and a proportionate addition to the weight of the gun without any commensurate advantage; and even for the bombardment of a fort or town (and this is an important point), a wide diameter is extremely bad, as it reduces the terminal velocity of a shot descending by its own gravity, and thus materially lessens the force of the blow; but these are points which would require a distinct lecture to treat them as fully as their importance deserves.

We will now consider the relative weight of the two kinds of guns;

and weight, when necessarily so limited as on board a ship, will require a more rigorous comparison than appears to have been the case at many of the public trials; we will assume the balls to be round and of the same weight and diameter, the charges of powder and lengths of bore to be the same, with the same thickness of metal for resisting the explosion; taking these as fixed data, the rifle, in order to have the same uncut substance of metal as the smooth bore, will require its external diameter to be increased by such an additional thickness of metal as will compensate for the incisions in the bore of the gun caused by the grooves; it must not, however, be inferred that a coating of metal of the same thickness as the depth of the incisions, when added to the outside, will place the rifle on a parity of strength with the smooth-bore, for when, in cutting the grooves, metal is abstracted from the interior of a gun, the diameter of the bore becomes practically increased by double the depth of the grooves.

The transverse sections of the two bores will then be the same as two circles with these different diameters, the circles comparing with each other as the squares of their respective diameters, the thickness of metal required to give each gun the same resisting strength will necessarily bear the same relation; the simple cutting of a groove in the interior of a gun consequently requires far more than the addition to the outside of the gun of the metal taken away from the inside.

But the substance of the rifle will have to be increased beyond this again, for the more extended the surface the weaker it becomes; a hundred fathoms of two-inch rope will not bear the same strain as will a single fathom of the same rope, the chances in favour of weaker parts appearing in the longer length being as one hundred to one.

But if I enter into a minute measurement of the relative strength of the two guns, there will be the air in the grooves assisting materially in developing the gases, and there will be the detention of the ball by the friction of the grooves, all combining to throw an increased strain on the gun, which must be met by an increase to the thickness of metal; if therefore the exact conditions of the comparison be adhered to by the charges and balls being of equal weight, the rifle will be relatively weaker, or if the guns are to be of the same strength, the weight of the rifle must be considerably added to.

Probably, second to none in its direct bearing on the absolute power of a man-of-war at close quarters, is the time occupied in loading, for if we take two vessels of equal force, and the one can fire twice as fast as the other, the former will relatively be twice as powerful as the latter.

No one will deny that a rifle even on shore will occupy more time in loading than a smooth-bore; but at sea, and particularly in rough weather, the difference in favour of the smooth-bore will be still more marked, as the roll of the vessel has then to be watched, and the charge rammed home at a particular period of the roll, and if from any cause the loading has not been completed at the proper moment, it will have to be delayed until the next roll, and so on, possibly (should there be any difficulty in the operation) for several subsequent rolls, pausing between each for the favourable moment to occur, for while the muzzle

of the gun is inclining to leeward with the lee roll, and with the end of the rammer very possibly dragging in the water, it will be impossible to proceed with the loading, and force the charge, as it were, up hill; indeed, during a lee lurch, it is as much as the numbers 3 and 4 can do to keep the charge from falling overboard, or the rammers from being washed away, and which will occasionally happen notwithstanding every care being taken, a stiff junk wad for instance will frequently delay the loading for several rolls.

Those gentlemen who may have witnessed the loading of a lee gun in a ship rolling heavily, will best appreciate the difficulty, and I may add, danger which at times attends this apparently simple operation, for should the hook of the traintackle straighten (and the whole weight of the gun will be thrown on it as the ship lurches to leeward), the numbers 3 and 4 would probably be crushed between the breast of the gun and the ship's side, and the difficulty and danger will of course be much increased by anything tending to protract the loading.

I have thus endeavoured to show that the time occupied in loading the rifle will be much longer at sea than on shore, and it is not too much to assert, that with a rolling motion, the smooth-bore may be fired twice as fast as the rifle.

These are serious facts, for a vessel's armament will become nearly nominal if the power of employing it can be so greatly circumscribed.

There is another evil in the rifle affecting its accuracy at a long range, which occurs when the centre of the shot and the shot's centre of gravity do not coincide (from the metal of the shot not being homogeneous throughout its structure), and which with perfectly spherical shot fired from a smooth bore will never arise, as the shot's centre of gravity, if it were not in its proper position when the shot left the muzzle of the gun, would of its own accord almost instantly assume its right place without interfering with the correctness of the shot's flight; but in the case of the rifle shot, the centre of gravity will be incessantly struggling against the unnatural position in which it was forcibly detained by the rotary motion, and as that motion gradually slackened, the centre of gravity would untimately triumph, and the protrusions and abrasions on the shot's surface would then find another and less accurate axis, and cause a deviation of the shot from the direct path.

I have now detailed a variety of special circumstances interfering with the employment of rifle guns at sea, many of which very probably might never have occurred to any but a sailor accustomed to the working of great guns at sea.

I have endeavoured to show that before rifle guns can be employed in our ships of war, the rifle error must be got rid of.

That the rotary motion causes a deflection of the rifle-ball to such an extent when it touches the water, as to be nearly as dangerous to friends as to foes.

That the rotary motion prevents ricochet firing.

That the slow passage of a shot through a rifle-bore renders a correct aim at sea nearly impossible.

That the detention of the ball by the rifle grooving, or by muzzle and

other grips and obstructions in the bore, is most dangerous, as directly tending to burst the gun, besides preventing the same amount of charge being used in the rifle as in the smooth-bore.

That the low rate of velocity in a rifle-shot prevents penetration and an accurate aim, besides reducing the shot's range, and from requiring an increase to the gun's elevation, adds materially to the difficulty of hitting the object, by the increased curvature of the shot's path.

That the weight of the rifle gun is relatively considerably greater than that of the smooth-bore.

That the time occupied in loading the rifle being so much longer than with the smooth-bore, is a direct loss of power.

That the forced position of the centre of gravity in the rifle-shot causes a deviation of the shot at the end of its flight.

And as to the greater liability of the rifle gun to wear away, its incapacity for firing shells and molten metal, and its greater expense, they are such palpable facts that they need not be entered into in the present sea-view of the gun, and when in addition to what I have already adduced we have the authority of Sir Howard Douglas that the smooth-bore is as accurate as the rifle, I sincerely trust that whatever advantages the rifle gun may be supposed to possess for military purposes, it will not hastily be concluded that these advantages are in the least degree applicable to the naval service, or that the serious defects I have been enumerating, can ever be remedied sufficiently to render rifle guns adapted for ships of war.

I will now proceed with the second part of my lecture, "The proper armament for ships of war," and my remaining time being limited, will address myself to general principles rather than to minute details.

By the introduction of armour plating a new feature has arisen in naval warfare, which necessitates a certain modification, rather than any sweeping change of the existing means of attack when directed against ships protected with a covering of metal.

It appears however by the public papers that there exists a very prevalent opinion, that because a certain thickness of iron has to be penetrated, there must of necessity follow a total change in naval warfare, and that previous experience will be inapplicable; that even such an established fact as "the more numerous the guns, the greater will be the prospects of success," will no longer apply, and that a chance hit from only one or two guns of an immense, and (as I will presently show) unnecessary size, will, for the future constitute, our only means of insuring victory.

I can easily imagine that the conversion of ships into steam-rams will involve changes of the most sweeping character, both in the actual construction of the vessels and in the means of attack and defence; but it is difficult to perceive how the mere penetration of a certain thickness of iron can require enormous guns throwing shot of great diameters, while the very extent of the diameters (by every known rule in gunnery) actually militates against the required penetration.

To enable a shot to penetrate a substance so highly resisting as

wrought iron, a very high initial velocity is required with a considerable concentration of weight under a small diameter, and which is directly opposed to the low initial velocity and large diameters so much advocated by some, but the very size of the guns by limiting the number carried, is in itself one of the strongest reasons for their exclusion.

The real force of a ship of war, so far as her armament is concerned, *will consist of the number of shot she can discharge in an effectual manner in a given time*, no matter whether arising from the greater efficiency of her crew, or from the number of her guns; and this is no new theory, though so set aside by the fond idea which would concentrate a broadside's effort in a single shot (on a single cast of the die), rather than accumulate the *chances of hitting* and of ultimate success by a number of guns.

The employment of unwieldy guns requires the various appointments and gear to be of an increased size, and a greater length of time occupied in their use is the natural consequence; and it is evident that the mere operation of loading and ramming home a shot (particularly if it be of some 300 or 600 pounds weight), will, with a ship rolling heavily, be a work of no inconsiderable difficulty, and occupy much valuable time.

The displacement of a ship being a fixed quantity, the total weight available for the armament will be equally fixed; the question is therefore, whether it be desirable that this weight should be distributed amongst a few guns of immense size, or amongst a greater number of a lighter weight, for on this the true power of the vessel as a man of war will depend.

I have already touched upon some of the requisites for insuring penetration; let us however assume that in this age of improvement an impenetrable plating of metal may be forthcoming for our ships, the question will then arise: How are we to overcome a difficulty apparently insurmountable?

The difficulty however admits of a readier solution than might at first sight be supposed, for a man of war can never (even by the aid of an impenetrable plating of metal) be rendered everywhere impervious to shot and shell; the very guns she carries will constitute her weak points, and the heel of Achilles will be found at the ports in which these guns with their protruding muzzles are placed; and for penetrating the weak defences at the ports, for the destruction of the crew congregated at the guns, and for effectually silencing the guns themselves, no huge description of ordnance difficult to aim (or even handle in a sea-way) is required, for all this can be accomplished with greater rapidity and prospect of success by the smaller guns; these, if constructed on the true gunnery principles of high charges of powder and small diameters of shot, and of greater lengths, will be infinitely preferable to larger guns, even for the very purpose of penetrating such armour plates as are now made. The employment of guns of an extreme size is moreover a misapplication of power, an improper adaptation of means to an end.

The employment of ordnance with great diameters of bore and

fired with merely low charges of powder, is the rudest and most imperfect method for compassing penetration, if even that be possible under such a system; the resistances increase as I have before observed as the squares of the diameters, there must therefore be a corresponding increase to the charges of powder, and to give to a 13 or 15-inch shot the requisite high velocity for penetrating an armour plate, and for obtaining an extreme range with but a slight curvature in its line of flight, will require such an amount of powder as might be attended with the most disastrous results in time of action, if in the confined space of a ship's decks an accidental explosion took place during the progress of the powder to the gun. Eighty or 100 lbs. of powder exploding in this manner would probably destroy the crews of several guns, and decide the action by paralyzing the remainder, besides inflicting most serious damage on the vessel. And even if we merely retain the old proportion of one-third the weight of the shot for the distant charge, we shall have a charge of powder of 200 lbs. weight for the 600-pounder gun, the explosion of which would cause a loss of life fearful to contemplate, and probably decide an action which would thus hang on the safe transit of a cartridge; the fate of a ship being literally carried in a powder-box.

Any person who has witnessed a sustained fire from a ship's weather guns, must be well aware of the constant risk of explosion from the flakes of fire (which are borne backwards into the ship through the weather ports) igniting the charges as they enter the guns; or, suppose a stray shell knocked over the powderman, it will be seen that the danger arising from having such masses, such *sacks* of powder *in transitu* to the guns, can scarcely be exaggerated.

As for what has been termed the crushing effect of monster guns, when fired with low velocities, it is but feebly anticipating the peculiar office of steam-rams, and thereby sacrificing all the multiplied chances of hitting offered by the more numerous smaller guns.

It appears from an account of the trial of one of the 20-ton guns conducted under favourable circumstances on shore, that some ten minutes were occupied in the loading, ramming home, and firing, during which some 20 rounds might have been fired from an 8-inch gun, as 3 rounds in 54 seconds have been the common practice on board the Excellent; if, then, we multiply these 20 rounds by 6 (the number of 8-inch guns whose gross weight will equal a 20-ton gun, and I by no means infer that the 8-inch guns are the proper guns), we shall have the astonishing number of 120 chances to 1 in favour of the 6 smaller guns, when opposed to the 20-ton gun; but let us reduce the chances still more by supposing that the 8-inch guns are only capable of keeping up a sustained fire of a round a minute, and we shall still have 60 chances to 1 in favour of them; but put the question in any form, and the chances will always greatly predominate in favour of the more numerous though lighter guns; assuming always that these latter are capable of accomplishing the amount of penetration I have already been describing.

It may fairly be asked what single gun, however powerful, could be loaded and remain uninjured under the torrent of fire which the more numerous guns could pour on it, and if such be the case with the fire

of only six guns, what must be the terrific effect of broadsides from vessels of 50 and 100 guns, when directed continuously on only one or two guns? and any single shot (be it remembered) striking the heavy gun, would probably so damage it as to silence its fire; even a wooden three-decker (*with proper guns* and in good gunnery order), if alongside of a cupola ship, by the very torrent of fire she could pour in, would render it impossible for the latter even to discharge the few guns she possessed.

As regards the actual working and firing of great guns at sea, it is only persons practically conversant with the subject who can form any adequate notion of the many serious difficulties which attend even the simplest operations, and which are not to be found in the Artillery practice on shore; observe the manner in which a naval gun is hampered with breeching and tackles, the mode of taking aim, and of conducting every operation while a ship is plunging and rolling in a sea-way; besides, there is the extreme danger from so many tons of dead weight on moveable trucks, which, by the mere rolling of the ship, might at any moment be put in violent motion far beyond the power of the crew to control.

Let a gun, for instance, carry away its breeching, and it becomes a battering ram, rushing wildly about as the vessel rolls from side to side, unapproachable by the men, and crushing everything in its headlong and uncertain course; a 32-pounder of only 56 cwt. breaking loose in heavy weather on the lower deck of a ship of the line, would take command of the deck (as it is termed), and could only be brought under control by piling hammocks in its way, and whilst adrift it might endanger the very safety of the vessel by bursting open a port.

But if, instead of a 56 cwt. gun, we substitute guns weighing 12 and 20 tons, and they went adrift (and every gun at the instant of firing with side tackles let go, becomes semi-detached) they would become battering-rams that might force outwards the very timbers of the ship, and even sink her in an instant; and to show this is no imaginary or improbable idea, let us take the case of a weather gun, and suppose that the ship at the instant of firing, takes a sudden lurch to leeward, if then both the charge of powder and lurch happened to be very heavy, the gun under the combined forces would almost leap in, and bring such a strain on the breeching-bolts and breeching as might be far beyond their power of resisting.

The firing of weather guns with the distant charge and the ship heeling over, or rolling from side to side, is always an anxious duty, from the double momentum to which the gun is then subjected, and very often it will be found that the mere size of a vessel's guns renders it absolutely unsafe to cast them loose, when lighter guns might be used with good effect, and with comparatively little risk.

We have hitherto been considering the case of guns mounted on the common truck carriages; but take a heavy gun mounted on any of the modern slide carriages, and fire it ahead or astern, with the ship rolling heavily, and there would be the danger as the ship rolled, of the gun falling over on its side, owing to the powerful lateral leverage brought into play by the height of the centre of gravity above the deck (and

it may easily be seen how soon a line dropped from that centre would fall outside the narrow base on which the whole rested), and if during the critical moment, while the gun was recoiling, the ship should give a heavier roll than usual, the gun would be over and to leeward in an instant, falling with a crushing force on the ship's timbers, and very possibly forcing them outwards.

Should, however, a smaller gun turn over in this manner, the injury to the ship would probably be slight, and be confined merely to springing a beam or staving in the deck.

I have before drawn attention to the delay, and consequent relative disadvantage (compared with smaller guns), arising from the great increase to the weight and unhandiness of almost every article connected with very heavy guns, and I now wish to observe that for obviating this machinery will not avail, and even if it forwarded the one, it would equally advance the other, but for many of the operations machinery is inapplicable, nor would an increase to the gun's crew be of any use, for there are many of the operations, such as sponging and loading, where the powers of a number of men cannot be applied.

I have already alluded to the danger arising from such heavy charges as one or two hundred pounds of powder exploding by accident in their conveyance to the gun; but there is also the danger of guns with great thickness of metal bursting in cold weather (the thermometer below zero, for instance), from the sudden expansion of the interior of the bore under the intense heat which the explosion of large charges of powder would generate; and, 10° below zero is by no means an uncommon degree of cold on the North American station, as I can myself testify. The breaking of a cold glass tumbler when hot water is suddenly poured into it is an exact illustration of this.

The first part of my lecture has been devoted to prove how totally unsuited for naval warfare are rifle guns, and in the second part I have endeavoured to point out the urgent necessity for arming our ships with the greatest number of *efficient* guns they are capable of carrying.

I will now add a few words on the general character of the future armaments of our men of war, to which my remarks and illustrations have been gradually tending.

I need scarcely repeat that, for the reasons already adduced, smooth-bore guns ought to be exclusively employed in ships of war.

That the diameter of the gun's bore should never exceed 7 or 8 inches.

That the internal surface of the bores should be of steel, in order to be as hard, or harder, than the projectiles employed.

That the bores of the guns should generally be much longer than at present.

That the strength of metal in the guns should be sufficient to withstand far heavier proportionate charges than those at present employed.

That with the exception of a gun or guns pointing directly forward and aft, a ship's guns should be mounted on the broadside, and be as numerous as the displacement of the vessel will permit.

That a similarity of gun should be the prevailing feature in all classes of ships.

There are, of course, many other improvements, such as air chambers in the middle, and more particularly in the rear, of the cartridge, by which the efficiency of the smooth-bore might be greatly promoted; and there is the important question of windage, which is so little mastered at the present moment that it remains undetermined whether windage should be a constant quantity, or bear a direct relation to the diameter of the shot; there are also the proper forms for longitudinal shot and shell.

But I must abstain from entering on so wide a field as the improvements of the smooth-bore. I feel, however, every confidence in asserting that these guns are capable of very great improvement, and of realizing all we seek for in a naval gun.

I wish, before concluding, to refer to the undue prominence which has lately been given to the operation of training guns, and which seems to have led to the invention of cupola ships and twin screws, the one proceeding by a moveable platform, the other obtaining the same apparent result by moving the vessel herself, both of these systems being exclusively confined to the lateral movement or training of the gun to the right or left hand.

Now, the mere training of the gun does not necessarily involve the hitting the object. It is, indeed, but a small part of the necessary preliminaries, and a part about which there has never been any difficulty whatever, as the handspikes and side tackles move the gun with amply sufficient rapidity, and when the gun's muzzle has been brought in the direction of the object (which by this means can be done almost instantly) the subsequent labour will be of the lightest character; indeed, the smallest heave of the handspike is all that is required when the gun is nearly on with the object; but, as I have just observed, this is only the lateral movement of the gun. There is the vertical, or "elevation," to be equally considered, that being as essential in hitting an object as training.

I do not apply the term "elevation" as restricted to the tangent scale, but to that necessary movement of the gun, by which the muzzle is brought into such a position as to pass with the motion of the vessel as much above as below the object aimed at, and as this mean position will alter with every change of the gun in a lateral direction, it is obvious that increased facilities in the lateral movement cannot be very valuable, unless accompanied by corresponding improvements in the vertical.

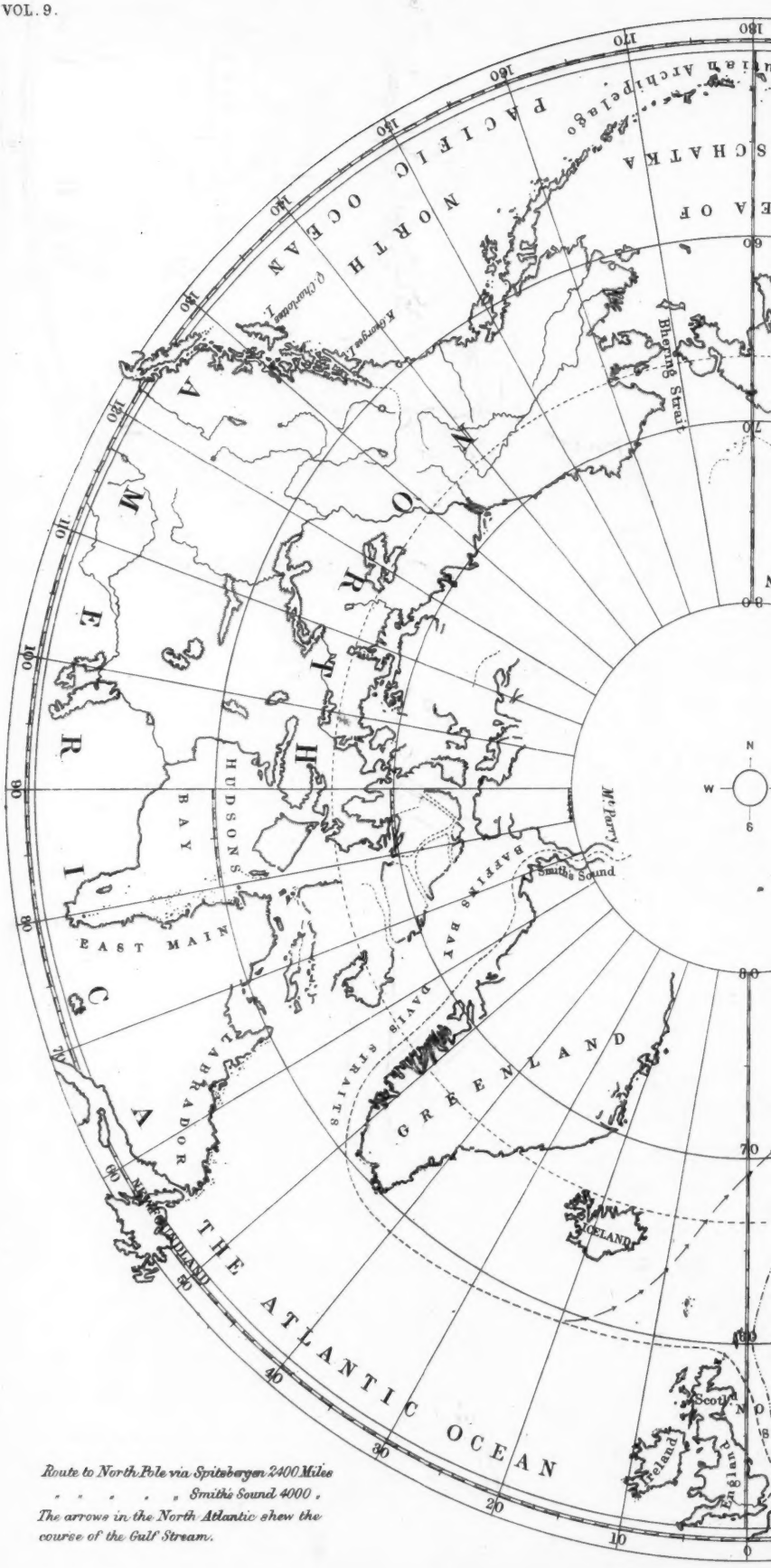
To secure this one point, the projectors of cupolas in following up the single idea (which too frequently blinds the inventor to collateral issues) have entirely overlooked the very serious fact that unless they contemplate firing through their own vessel's decks, they are at a dead-lock when firing to windward with their ship heeling over; for if the cupola ship be heeling over, say 10°, and assuming that its gun can be depressed to that extent (and which I doubt being possible), the gun can only be fired horizontally in the single position of "right-abeam." The moment the muzzle is moved to the right or left of

that position, the ship itself intervenes, the hull extending fore and aft as a tangent to the circle around which the cupola gun is revolving. From this cause alone a cupola ship, or any ship with merely central guns, might, in blowing weather, be approached from to windward with impunity, and certainly without the slightest fear of receiving from her a shot between wind and water, as this would require a depression of the guns far beyond the depression given to compensate for the inclination, and to bring the gun into a horizontal position. With respect to aiming with the helm, it will never be practised in anything beyond a boat, and in ships under canvas it would be out of the question; but for contributing to the celerity of movement required in a steam-ram (both in attacking and for avoiding an attack), anything which will conduce to a rapidity of movement will prove of the highest value in time of action; indeed, under any circumstances, a ship which answers her helm quickly will possess a great advantage at sea.

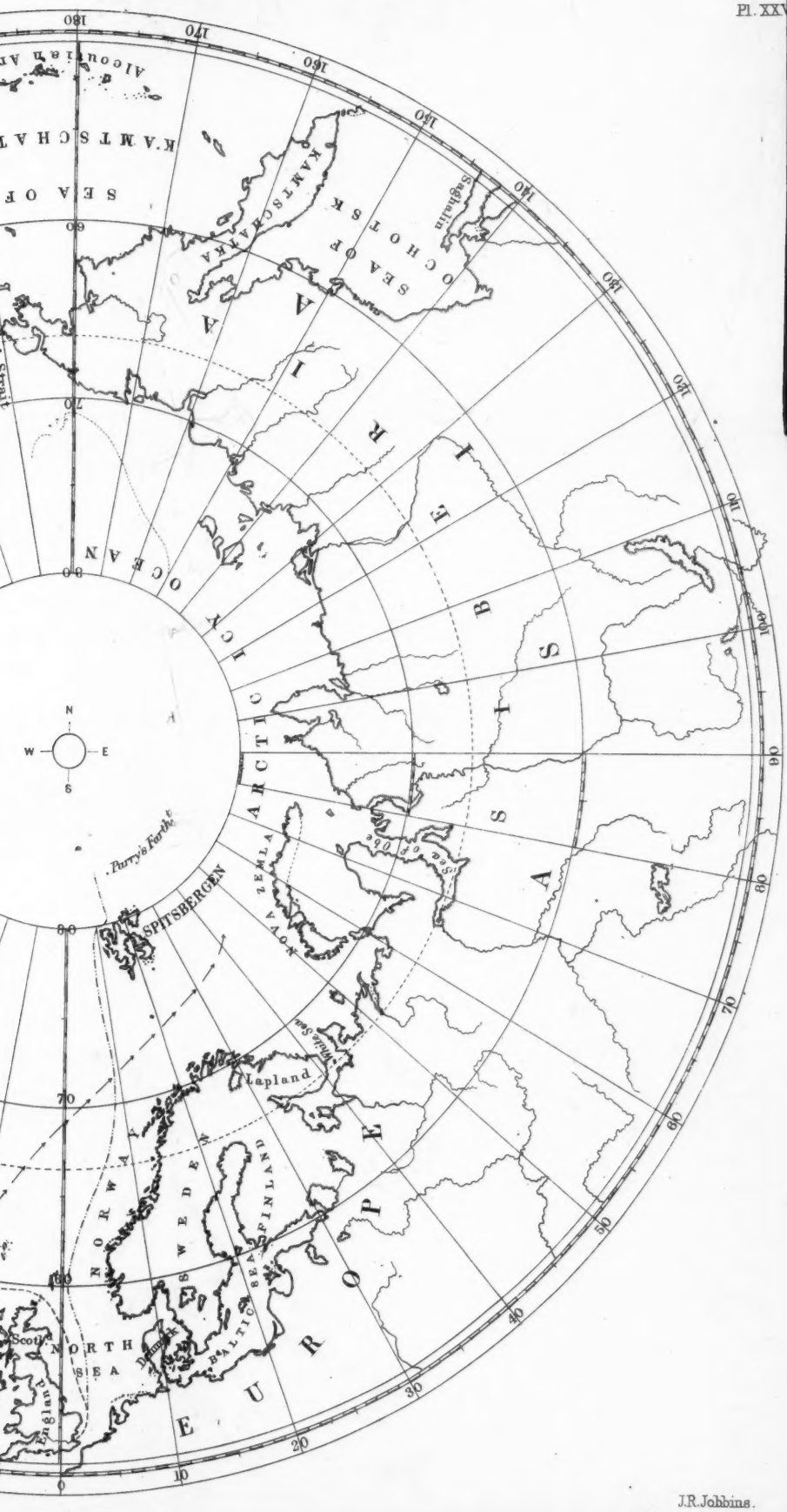
The manufacture of guns being rather a land than a sea question, cannot properly be included in this lecture; but I should not be doing justice to naval interests if I omitted to make some allusion to the future disposition of the naval rifle guns now in store, and which, if rejected for military purposes, might have their grooving bored out, and stout tubes made under the Bessemer process inserted instead (both being then heated and cooled from the inside), thus an efficient class of guns might be produced at a comparatively small cost.

But I must not trespass longer on your time. I have endeavoured to present you with a sea-view of the important subjects of my lecture, and in no other aspect can they be regarded without sacrificing the great interests of the country; and should a committee on these subjects be ever appointed by the House of Commons, I trust it will be an instruction to the Speaker that the members of it be sent to cruize between Cape Clear and Ushant in one of Her Majesty's ships, and there draw their report, which, if they are not incapacitated by the motion, will probably be more valuable to the country than if it emanated from one of the committee-rooms of the House of Commons.

Such a technical subject as naval gunnery can be only properly handled by naval men, who are now much better able to deal with these questions than formerly, naval gunnery being fortunately viewed in a very different light than when the first pioneers of the system had to struggle against the ridicule and openly expressed contempt of the great body of the Service; indeed, so thoroughly has the system of the "Excellent" pervaded the naval profession, that Officers who never entered that ship are to be found writing first class papers on naval gunnery; but let me, nevertheless, as one of your oldest Gunnery Officers, in conclusion add, as the result of a long experience at sea, *that all naval gunnery is utterly worthless unless it can be combined with the most thorough seamanship.*



Route to North Pole via Spitsbergen 2400 Miles
" " " Smiths Sound 4000 "
The arrows in the North Atlantic shew the course of the Gulf Stream.


ARCTIC OCEAN
SEA OF KAMTSCHATKA
SEA OF OCHOTSK
KAMTSCHATKA
ASIA
Behring's Strait
Sea of Kamtschatka
Alleutian Ar.
NORTH AMERICA
Parry's Farth.
SPITSBERGEN
NOVA ZEMLA
White Sea
Lapland
NORWAY
SWEDEN
FINLAND
Scotland
NORTH SEA
Denmark
BALTIC SEA
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J.R.Jobbins.

Evening Meeting.

Monday, April 3rd.

REAR-ADMIRAL R. COLLINSON, C.B., in the Chair.

NAMES of MEMBERS who joined the Institution between March 20th and April 3rd.

LIFE.

Williamson, James, Captain 23rd Royal Welsh Fusiliers.

ANNUAL.

Blacker, William, Capt. 12th Roy. Lancers. 1*l.*
Graham, H. L., Cornet 12th Roy. Lancers. 1*l.*
Turner, W. W., Colonel 97th Regt. 1*l.*
Grant, J. M., Capt. Madras Staff Corps. 1*l.*
Warren, Fredk., Com. Roy. Navy. 1*l.*
Comyn, T. R., Lieut. 1st Tower Hamlets Engineer Volunteers. 1*l.*
Bringes, John Fredk., Lieut. 1st Tower Hamlets Engineer Volunteers. 1*l.*
Cuming, W. H., Commander R.N. 1*l.*
Briggs, John, Captain 82nd Regt. 1*l.*
O'Driscoll, T. W., Ens. 82nd Regt. 1*l.*
Ingles, John, Lieut. Roy. Navy. 1*l.*

POLAR EXPLORATION.

By Rear-Admiral E. OMMANNEY.

THE subject which I have the honour to bring before you this evening is the feasibility of exploring the Polar Regions, and of taking into consideration that route which presents the best hopes for attaining the desirable object of reaching the Pole itself.

During my Arctic services, my mind was strongly impressed with the conviction, which I have since retained, that if the Pole is to be gained, our chief hope of success must be by making Spitzbergen the base of operations. In 1852 I submitted my views on this subject to the First Lord of the Admiralty.

The strong desire to obtain further information respecting the condition of our globe at the Pole itself is rapidly gaining strength, fostered by the leading scientific Societies and the most eminent men of the day, together with those voyagers who have been engaged in Arctic enterprize. Captain S. Osborn's very able paper, read before the Royal Geographical Society, has again aroused with renewed vigour the spirit of enterprise for Arctic research.

You are aware that there are before the public two propositions for proceeding to the North Pole; the one making Smith's Sound the base of operations, the intention being to leave the ships in a secure position, from whence it is proposed to reach the Pole by travelling over the ice with sledges, making a sledge journey of it, on the supposition that land will be found extending itself towards the Pole from Smith's Sound. The other is from Dr. Petermann, who advocates in two very able and well digested papers, the course of penetrating into the icy seas between Spitzbergen and Nova Zembla, on the theory that a warm current flows from the coast of Norway in that direction into the Polar Sea, extending itself to the vicinity of the Pole, and that the influence of this warm current of water is productive of raising the temperature of the sea and climate, thereby creating spaces of open water, consequently that we shall find a sea more free from ice obstructions, and available for navigation contiguous to the Pole. The chief obstacle to surmount he considers to lie in the outer barrier of floes and packed ice, forming a moveable band of about five degrees of latitude in extent; so that, after pushing your ships through this barrier, they would enter a sea easy of navigation, extending to the highest latitude, no doubt to the Pole itself. Certainly, on looking at the globe, where can we find a more favourable point to enter the Polar Sea? We have in the Spitzbergen Seas the largest and widest openings from the North Atlantic Ocean; the Spitzbergen Islands have been circumnavigated—and their western shores are stated to be clear of ice in the summer. On glancing at the chart, you will observe, that the Polar region to be explored is that vacancy contained within the circle of the 80° parallel; but it is necessary to state that up to the present time no attempt has been made to reach the Pole with suitable vessels armed with proper instructions; for you will find in all the voyages to these regions that the seas were abandoned by order at the very best season for making an advance to the Pole.

With reference to former Government expeditions which have left this country with a view to reach the Pole, viz., those of Phipps, in 1773, Buchan, 1818, and Parry, in 1827, by way of the Spitzbergen Seas, though unsuccessful, we cannot but admire the courage, skill, and intrepidity which marked the proceedings of these voyagers; but we now find from recent experience, gained in the Franklin searching expeditions, that their failure and disasters may be attributed in a great measure to the form and class of vessels of those times, for instead of selecting an old bomb vessel or whaler with flat sides, formed something like an oblong box, we should now select steam vessels of the clipper form. Vessels of this form rise readily to pressure between masses of ice; when this is the case the fear of being crushed is

removed at once. With the old-fashioned vessels, owing to flat sides and bluff ends, they resisted the nipping of the ice, which crushed right through the vessel or passed entirely over her; now in threading your way through the pack ice, or lanes of water, the sharp clipper bow turns aside the pieces of ice without impeding the progress of the vessel, whereas with the old bluff bows of the discovery ships, the ice was frequently accumulating across the bow; therefore, assuming that we are setting out in the present day on a Polar exploration *viâ* Spitzbergen, we shall commence operations with a new element never applied in this sea before, viz., a clipper-formed vessel aided by steam propulsion.

I would also call to your notice the fact that we have made but one attempt in this country to reach the North Pole, viz., that of Parry, in 1827; all the other expeditions have been undertaken with a view to make N.W. and N.E. passages to India and China.

Of the two routes now under discussion the majority of Arctic officers are in favour of making the attempt by the Spitzbergen seas. Certainly these seas offer the shortest route from Great Britain to the Pole. There are so many advantages to be advanced in behalf of making Spitzbergen the base of operations, that I am induced to give that route my strongest recommendation in preference to proceeding *viâ* Baffin's Bay, and for the following reasons:—

1st. The Spitzbergen seas are more free from ice than any other part of the Arctic seas.

2ndly. The Western shores are clear of ice in summer, affording an open navigation between a depôt fixed at Spitzbergen and England.

3rdly. It affords reasonable hopes for effecting the search of the Polar region in one season.

4thly. There are good harbours in Spitzbergen; the climate is more temperate than that of Smith's Sound; animal life is more abundant; driftwood for fuel is found on its shores.

I maintain that hitherto no proper effort by a suitable vessel has been used to reach the Pole; that we never sent an expedition in that direction provided with the means of wintering and exploring at the proper season, consequently the Spitzbergen seas were abandoned at the most favourable season for immigrating.

For instance, let us take Parry's voyage, in 1827, who made a noble effort to reach the Pole by means of dragging boat-sledges over the ice. First, he sails to 81° 5′ N. in June; the sea was clear of ice; deposits a reserve supply of provisions on Walden Island for his boats; then places his ship in an excellent safe harbour (*Hecla Cove*) for security whilst making his boat-sledge journey. The boats having sailed north to the margin of the ice, his in-travelling commenced on the 24th June. After much toil and endurance, using unparalleled exertions, he reached lat. 82° 45′ N., and long. 19½° E. on 22nd July, the highest northern position ever attained; but here his progress was baffled by an obstacle he was not prepared to contend with, for in addition to the many other impediments which they had to encounter, they found by their astronomical observations that the ice on which they were travelling was being carried to the southward by a current at a more rapid rate than they

could overcome in dragging the boats. With minds filled with disappointment the party retraced their steps, and on the 11th August reached the *open sea*, in lat. 81° 34′ N. The boats were launched. They finally quitted the ice after a sojourn of 48 days upon it. The boats sailed to Walden Island, the depôt, where they rested and enjoyed the luxury of a blazing fire, made from the driftwood found on the beach. The boats returned to the ship, and Parry came home.

On leaving the coast of Spitzbergen, Parry makes the following observations respecting the extent of open sea:—

"It was really wonderful to see that upon this whole North coast of "Spitzbergen, where, in May and June last, not a hole of clear water "could be found, it would now be equally difficult to discover a single "heap of ice in any direction.

"Before the middle of August, when we left the ice in our boats, a "ship might have sailed to the latitude of 82° without touching a "piece of ice, probably no difficult matter to reach the parallel of "83°."

Upon looking closely into the proceedings of the boat-sledge journey, I am forcibly struck with the frequent impediments which retarded their progress, in the shape of lanes of water, necessitating the operation of launching and hauling up the boats several times in a day's journey. Now this I regard as a very hopeful prospect to future operations by steam-vessels, shewing to me that the ice is sufficiently loose to penetrate. I believe a screw vessel might have threaded her way through these lanes of water and gained in the same number of days the same distance which it took them weeks of toil to accomplish.

I find another very important observation made by Parry, indicating thereby that the character of the ice is not that of a permanent body, but of such a nature as to favour the advance of steam-vessels. He states, when compelled to abandon his boat-sledge journey—

"At this extreme point, 82° 45′ N., of the journey the ice did not "shew any indication of a proximity to a permanent body of ice; the "continued drift of the body shewed there was an open space both in "the direction of its course and in that it had drifted from; the sea "was 500 fathoms deep; and there seemed nothing more to impede a "vessel's course than there was met with near the margin, that is, a sea "covered with broken fields of ice, which might open or close according "to wind or tide."

From this remarkable passage I infer that with the aid of steam power we can surmount the icy obstacles in the Polar region.

Now what do we learn from this noble exploit of Parry? The useful warning that travelling should not be commenced in July and August, and not to quit the Polar Sea in August, which is the very month of all others most favourable for Polar exploration by steam vessels.

In perusing the accounts of Northern voyages we meet with assertions that vessels have sailed near the Pole. One of the most adventurous and scientific of our whaling voyagers was Scoresby, who on one occasion attained to the latitude of 81° 30′ N. The following extract from his work is indicative of open spaces of water, which at certain seasons present themselves to the explorer:—

"On the morning of the 24th May we considered ourselves nearly a "degree to the northward of Captain Phipp's furthest advance, our lati- "tude being estimated at 81° 30′ N., longitude 19° E. Here a similar ex- "panse of sea presented itself as on our western reach. The margin of "the ice continued to trend E.N.E. as far as was visible, and from the "appearance of the atmosphere it was clear that the sea was not in- "commoded by ice between E.N.E and S.E. points within 30 miles, or "limited by land within 60 or even 100 miles of the place of the ship. "Had the purport of our voyage been discovery instead of whale fishing, "we should certainly have been enabled to add something more to our "knowledge of the globe in a region seldom attainable. Discovery, "however, being only in a limited degree compatible with our object, "considerations of prudence and safety induced our return."

In 1837 Dr. Whitworth, surgeon of the "Truelove" of Hull, who reached the latitude of 82° 30′ N., long. 12° E., says—"I am satisfied "that the probability of reaching the Pole by water is much greater "than by land, for we had in lat. 82½° N. an open sea to the N.E., quite "free from ice; no apparent obstacle presented itself to our progress; "we might have reached the Pole with the same ease and safety that "we reached the latitude we were then in."

The southerly drift, carrying with it such prodigious quantities of ice from the Pole, which Parry experienced, day after day, leads one to a very natural inference that there must be left in the rear, in the vicinity of the Pole, large spaces of open water. Now do not all these well authenticated changes in the Polar ice furnish reasonable grounds of encouragement, that with the aid of steam power, a successful exploration of this region may be thoroughly accomplished in one season?

I desire now to make a few observations as regards the adoption of Smith's Sound as a starting point for making a sledge expedition to the Pole. First of all, to gain this point in one season is quite a matter of uncertainty, and when you get there, you must wait all through the winter before you can commence ice-travelling. The ice in Baffin's Bay and Davis Straits generally presents a formidable obstacle to northern progress. You will perceive that Davis Straits is formed by that contraction of the coasts of Greenland and America, which contraction impedes the ice clearing out of Baffin's Bay before the summer is far spent. Icebergs likewise accumulate and ground in Davis Straits, thereby resisting the drift and retarding the passage of ice coming away from the north. Ships bound to the northward have to hug the coast near Opernavik, and hold on to the land ice, during the passage of the middle ice out of Baffin's Bay. All our Government expeditions have had to contend with this formidable pack ice in Baffin's Bay. In 1850, when I commanded Her Majesty's ship "Assistance," in search of Franklin, we were beset for six weeks near Opernavik; the summer season was far spent and wasted in this helpless position. In 1836, when serving under Sir James Ross, I well remember that neither our ship nor any one of the whale flats could advance north of Opernavik, owing to the ice not breaking up. From Dises we examined the margin of the main body of the pack ice down to the coast of Labrador, and forced our way through the pack into Akkak, a Moravian settlement.

M'Clintock, in the "Fox," in 1857, was arrested in Melville Bay; unfortunately, she was beset in August by the pack ice, fixed in a helpless position, destined to sustain the terrors of the whole winter, whilst drifting with the ice until the following April. This dreadful disappointment and trial cost him the loss of a whole year.

Her Majesty's ship "North Star," in 1849, was driven into Wolstenholme Sound, and there obliged to winter. Ross, in 1848-49, was beset for a length of time in Baffin's Bay; his ships sustained damage.

Lastly, we have Kane's expedition, who, after encountering many dangers, attained the high latitude of $78\frac{1}{4}°$ N. in Smith's Sound. A barrier of ice closed up the straits. Having passed a second winter, and seeing no hopes of extricating his ship, he was compelled to abandon her to save the lives of his crew. From Kane's narration, I learn that Smith's Sound is the most dangerous navigation in the Arctic Seas; it possesses no such harbour as can be found in Spitzbergen $80\frac{1}{2}°$ N. The vast expanse of water seen by Morton in the Polar Sea would indicate unfavourably for success by sledge operations. This noble enterprize, which was despatched by the generosity and humanity of an individual, and the subject of a friendly Power, in behalf of our countrymen, should never be forgotten.

The remarkable drift of the "Fox" occupied a space of eight long dreary months, in absolute helplessness and danger. She was beset in Melville Bay August, 1857, and, after sustaining all the perils of the ice crushing and moving around her, she was released in Davis Straits 23rd April, 1858, having been carried about 1,200 miles.

We have another drift very similar to this in the case of the United States' searching expedition under "De Haven," 1850-51. Drifted with the ice helplessly from Wellington Channel to Davis Straits in about the same space of time as the "Fox."

Again, in the case of Her Majesty's ship "Resolute," abandoned off Melville Island, which drifted, without a soul on board, down to Davis Straits, where she was picked up by the United States' expedition.

These remarkable occurrences have left a lasting impression on my mind respecting the two ships (abandoned) seen by the crew of the "Renovation" on a large floe of ice near Newfoundland in 1851; for I incline to the possibility of these being Franklin's ships. In connexion with the above ice-drifts out of Barrow's Straits, some disruption of the ice may have drifted Franklin's ships towards the Parry Islands, and once in the influence of the current, so remarkably evidenced in the case of the "Resolute," they could be carried along, ice-borne, to Newfoundland. What a mystery might have been solved had these vessels been identified? They were damaged and unseaworthy no doubt, and sank into the ocean on the dissolution of the ice.

After the example and behaviour of the little "Fox," which was a clipper and screw steamer, I would have no fears for the safety of similar vessels if beset by the winter ice in the heart of the Polar regions.

Before however dismissing Smith's Sound, from all I have read and heard, it appears to me to be one of the most dangerous places in the Arctic Sea. And as I hold to the belief that we can approach the Pole by ships *viâ* Spitzbergen for the reasons before adduced, viz., that

spaces of water will be found, this state of things would render it impracticable to make exploration by sledges from Smith's Sound.

I would further add that the information to be sought for in making observations respecting the condition and phenomenon of the globe at its axis, will be the more valuable, according to the duration of time available for scientific research. Look at the advantages which would result from the visit of a ship to the Pole, compared to that afforded by a small sledge party.

Regarding the speculation whether land will be found about the Pole, all the observations and facts before us tend to show there can be no land of any extent; for at Parry's farthest north 82¾° N., he sounded the sea to 500 fathoms, but found no bottom. The large icebergs produced from the glaciers in Greenland are not seen north of Spitzbergen. We hear of no earthy debris, stones, or boulders being observed by the Spitzbergen voyagers lying on the ice-floes or fields. By the comparatively mild or modified severity of the Arctic climate at Spitzbergen 80° N.; the isothermal curve of temperature, corresponding with that of South Greenland and Hudson's Bay, shows almost conclusively that there can be no extent of land near the Pole capable of bearing glaciers.

Should circumstances involve the necessity of spending a winter at Spitzbergen, either in Fair Haven or Hecla Cove, we can find perfect security for a ship, with an ample field of useful occupation for both officers and crew, in making observations and gathering information for scientific purposes, from the high latitude of 80° N. As the spring advanced, the pursuit of game would be a source of amusement and health.

In the expedition of Clavering, in 1823, who conveyed the distinguished and learned President of the Royal Society (General Sabine) to Spitzbergen, to obtain pendulum observations; Sabine was landed on a small island near Fair Haven with two officers and six men. They lived there for three weeks, to conduct these experiments; in the meantime the ship made a voyage to examine the icy barrier to the northward. In this time Sabine's party killed no less than 50 head of reindeer.

In the expedition of Her Majesty's ships "Dorothea" and "Trent," of which Captain Beechey has left us such an interesting description, I extract the following passage from his work as showing what a large amount of animal life and food for man is to be found there. He observes:—

"On account of the mildness of the temperature, the shores of "Spitzbergen are frequented by multitudes of animal life; reindeer "were seen browsing at an elevation of 1,500 feet, the islands sur-"rounding Fair Haven clothed with lichens and other wild pasturage "for reindeer, which creatures are so abundant, that the island of Vogel "Sange alone supplied the expedition with 40 carcasses in high con-"dition, the fat on the loins being from four to six inches thick, and the "carcase prepared for dressing weighing 285 pounds. The boats of "the 'Trent' took four alive when swimming."

The first discoverers give marvellous statements as to the quantities of walrus which infest these shores. Bennett, in the ship "Godsend,"

visited Cherie, or Bear Island, in 1603, states that 900 to 1,000 of these creatures were killed in less than seven hours, and 400 loose walrus teeth collected at the same time on this island.

Spitzbergen you will perceive by the chart, is a group of islands between 76½° and 80¾° N. latitude; the largest is properly called Spitzbergen, the eastern part New Friesland. East of New Friesland lies North East Land, and is divided from the larger island by the Henloopen or Waygatz Strait, which is about 70 miles, and varies from 4 to 11 miles in breadth. South of New Friesland is Starn Foreland, or Edges Island, separated by a strait called Walter Tymens fiord, more than 50 miles long, by less than 10 wide; along the coasts of these islands, groups of smaller ones are dispersed, one goes by the name of the Thousand Islands, on the south coast of Edge's Island. On the western coast of Spitzbergen, at the distance of about 15 miles, is Charles Foreland, about 46 miles in length; there are several very good harbours around these islands, as Magdalena Bay, Smeerenburg, Fair Haven, Vogel Sange, the Narway, Love Bay, Hecla Cove in the Bay of Trenrenberg, and others.

The land is generally mountainous, the valleys are filled with glaciers which border the sea, forming a perpendicular precipice from 100 to 400 feet high; there are large tracts of low ground on which vegetation is very rapid in the summer. For the last two centuries productive fisheries of white walrus, &c., have been carried on in these islands; in the present day companies from Russia and Norway obtain considerable produce from these fisheries, likewise reindeer and eider down; no doubt these islands contain many natural productions but little known. Surely here is an abundant field itself for research.

Dr. Petermann assumes that the Gulf Stream extend its influence into the Polar Sea between Spitzbergen and Nova Zembla, which would cause a more navigable sea to be found in that direction; we have conclusive proof of this current flowing to the east of the North Cape. From Captain Beecher's valuable collection of records on which his useful Bottle Tenck Chart is compiled, I find one which is forwarded from Hammerfort by our Consul 2nd July, 1842, the bottle containing the record having been picked up at sea on the 1st June, 1842, off North Kyn, in lat. 71° 5′ N., long. 28° E. It is a letter written by the master of a vessel, placed in a bottle and thrown into the sea, lat. 60° N., long. 7° 30′ W., on 20th October, 1840, addressed to its owners, informing them that on the 18th October his vessel was run down by a brig in the night. Whilst in contact the whole of the crew went on board her with the exception of himself and one boy, the vessel was water-logged by the collision; on the 20th October an American barque took them on board and the vessel was abandoned. Our Consul in forwarding this observes, "it tends materially to confirm the prevailing opinion, that the Gulf Stream exercises considerable influence on the climate of Finmark." This was the third bottle record found in the same locality in a few years. In 1854, when I commanded in the White Sea, the French frigate co-operating with our squadron, picked up at sea, northward of North Cape, a cask of claret, covered with barnacles and weeds, supposed to have drifted in

the Gulf Stream from the Atlantic. At Wardhams, 70° N., I was told the sea is never frozen, nor are icebergs ever seen on that coast.

There are various speculations respecting the course taken by the Gulf Stream from the coast of Norway, but there is no satisfactory reason yet given to account for the large quantities of driftwood found on the north shore of Spitzbergen, possibly carried by some return current from the Polar region. From Phipp's voyage in 1773, we find the following interesting passage, on this subject, by an officer, after examining the north coast of Spitzbergen:—

"Being near a low island a boat was sent to examine it, about "7 miles in length. Dr. Irvine who accompanied the party stated that "there were lying on the beach, 16 or 18 feet above the level of the "sea, several large trees above 70 feet long, which had been torn "up by the roots, and others which had been felled with an axe and "marked out in 12 foot lengths. The timber was in no way decayed, "nor the strokes of the axe defaced in the least; likewise some pipe "staves and wood fashioned for use. The beach was formed of old "timber, sand, and whalebone. The middle of the island was covered "with moss, scurvy grass, sorrel, and a few ranunculus, then in flower; "two reindeer were feeding on this pasturage, one of which was "killed and found in good condition, well flavoured."

Mr. Crowe, formerly our Consul at Hammerfort, gives satisfactory proof of the feasibility of access with Spitzbergen, and its suitability for the habitation of Europeans. A small vessel of his own has ascended to half a degree further northward of the north extremity of Spitzbergen. Vessels of 40 tons have visited Walden Island. Mr. Shurastin, a Russian, passed 39 winters, without once having left Spitzbergen; and further, we know of the spirited voyages lately made by our sailing yachts to this part of the world, viz., those of Lord Dufferin and Mr. Lamont twice.

That the North Pole may be reached by sea is the opinion entertained by many experienced Arctic navigators and eminent men of the past and the present day, among whom are Parry, Beecher, Ross, Belcher; and General Sabine, one of the survivors of our discoverers in those seas, strongly advocates the attempt.

The Spitzbergen route offers so many advantages as contrasted with Smith's Sound, that I strongly recommend the attempt being first made from this direction rather than the scheme of sledging from Smith's Sound. It would take no more time to push vessels from Spitzbergen to the Pole than it does to make the passage from Davis Straits to Smith's Sound; and, moreover, it has this very great recommendation in its favour, viz., the chance of making the exploration in one season. We have at command a large amount of Arctic experience, and we know the right sort of vessel to use and the time to use it.

The Swedish Government are carrying on a survey at Spitzbergen, having taken up the project submitted by General Sabine to the Royal Society in 1825. The Officers on this service aspire to conduct an expedition to the Pole. Surely we shall never allow others to go in and carry off the greatest prize of Arctic exploration, after having hitherto been considered the leaders in these enterprizes.

In concluding, I desire to reply on the question generally raised, as to what is the use of these Arctic expeditions? I would simply ask, are not the laws of that subtle and invisible power, magnetism, which pervades all matter, inseparably mixed up with the safe navigation of our ships, now becoming universally constructed of iron. Will not fresh data on this science, as well as observations which would be collected at the Polar region relating to the condition and configuration of the axis of our planet, when worked out by the philosophers of the day, ultimately produce practical results for the benefit of mankind. God has given to man dominion over the earth, surely what more noble pursuit can occupy the mind of the human race than bringing to light the hidden treasures of the earth. Amongst the discoveries made this century in the Artic Seas, we find a small tribe of the human race cut off from the rest of the world by glaciers of ice in North Greenland; are not the sympathies of mankind and the Christian excited in their future welfare? and who can tell whether another remnant of fellow-creatures may not be found?

What brighter laurels adorn the naval crown than those gained by our great discoverers. Have not such enterprising men contributed to our lasting renown, as much as those who performed the most heroic deeds of warfare? I cannot do better than end this paper with the words of that great discoverer Parry, who says:—"Such enterprises "so disinterested, as well as useful in their object, do honour to the "country which undertakes them. Even when they fail, they cannot but "excite the admiration of every liberal and cultivated mind, and the "pages of future history will undoubtedly record them as every way "worthy of a powerful, virtuous, and enlightened nation."

Captain MAURY, late U.S. Navy: We have heard discussed, with a great deal of ability, here, as well as before another Society, the advantages of the Spitzbergen route. But before going into the merits of this or that route, we ought, I think, to ask ourselves the question, what is it we desire an expedition to the North Pole to accomplish? Is it merely to reach that black spot that is marked on the chart on that wall? I think not. I think the object is to explore the whole region that lies within that mystic circle of 80 degrees north latitude; a parallel beyond which, excepting at two points, no civilized man has ever penetrated. Those two points are "Parry's Cape," the furthest point at Smith Sound; and "Parry's furthest Point," north-west of Spitzbergen. All the rest of that region all round the Pole, is unknown; and it is that unknown region which we wish to explore. It is very true that the currents and the drifts of the sea are such that there is open water to be always found nearer the pole, in the neighbourhood of Spitzbergen, than there is in any other direction within our knowledge. But as we go north from Spitzbergen, as all who have gone there have reported, we come to ice; and when a ship gets fast in the ice, there is no telling when she will get out—the probabilities are that she will be drifted out southwardly, and be brought back into open water. So that if we adhere to the idea of having only *one* expedition, though I should be very glad to have two, then the question comes up, in what direction shall we send that expedition to explore the largest unknown regions, and accomplish the greatest amount of good? If we send the expedition up to Spitzbergen, the chances are, though the vessels may find open space, that they will be obstructed in their passage by ice. They may be lost. The probabilities, at all events, are that such an expedition will be baffled, and will come back with no other story than that it met the ice and could get no further. In that event, it will have made, considering the outlay, a very small contribution to the stock of human knowledge. I have learned within the last few days from a Russian

Officer, a friend of mine, that the summer before last, Lieutenant Kruzenstern, of the Russian Navy, in attempting to pass between Spitzbergen and Nova Zembla, had to leave both his ships in the ice, and to put back. The ships are there now. It is true that much is to be said about the mildness of the Spitzbergen climate, induced by those comparatively warm waters of the Gulf Stream, which we know come out of the tropical regions of the Atlantic, and find their way into Arctic seas between Iceland and Norway, softening the winds and tempering climates as they go. In reading Dr. Petermann's very interesting and able papers, I have been struck with the ingenuity and apparent force with which he dwells upon the facility of getting through that North Polar ice. In proof that it is an easy matter, he refers us to the manner in which Sir James Ross penetrated through the Antarctic ice. Without looking into this matter very closely, one might say ice is ice, and that if it was easy to penetrate through the ice into the comparatively open sea of the Antarctic regions, it would also be easy to penetrate through the ice into the open sea of the Arctic regions, latitude for latitude. Not so. If you look on that map that is suspended before you, and pitch a compass from the parallel of 65 north, all the way round the Pole as a centre, you see that, as far as we know, most of the circumscribed region is land. But if we take the corresponding latitude south, you will find that the whole region contained within a circle of like radius about the South Pole, would, with the exception of here and there an islet or a small group of islands, and, as far as we know, contain simply water. The prevailing direction of the winds in both regions is from the west towards the pole. Now the prevailing winds that blow upon those Arctic regions, pass over all the extent of land that is contained within that circumscribed circle. They drop at once mighty streams as they go. See all those large rivers in North America, in Europe, and in Asia, that flow into the Arctic Ocean, they are all made from the rains that these winds bear, and which are dropped down in their passage over the land. Of course, winds that blow over the land can take up from it but little vapour, for the land is dry, and cannot find the winds with moisture like the sea. These winds enter those hyperborean regions as comparatively dry winds. The consequence is that the climate there in the winter is much more severe, and the climate in the summer much warmer than it is in corresponding regions south. Now, when we turn to the south, we find that the winds as they approach the Polar regions, instead of blowing over land, blow over water. If the Antarctic winds drop down their moisture to-day in the shape of rain or snow, they take it up again to-morrow, because they are always in contact, not with land, but with water. To show the difference of effect which the mere direction of winds and the surrounding regions must have upon the climate of these two unknown regions, we have but to recollect that for every gallon of water that is condensed in the clouds, and showered down below, either as snow, or rain, or hail, heat enough is set free to boil five and a half gallons of water. The liberation in the air of such immense volumes of heat, is what causes the Antarctic regions, parallel for parallel, to be much warmer than the corresponding latitudes north. Consequently where Sir James Ross went, there he found the ice so (comparatively) loose, that he did not experience any difficulty, after finding an opening, in passing through hundreds of miles of it. And because that has been done there, Dr. Petermann argues, with a great deal of plausibility and ingenuity, that for like reasons you can pass through the ice of the north. I think not. I think this difference of climate makes the difficulty great, if not insuperable. I must say I have a great notion of the old English idea of slow and sure. If other explorers have gone to Smith Sound without steam, surely we can go there with steam? If Dr. Kane could go there in a little patched-up smack—for she was hardly anything else—why, surely we can go there in something better. If we can only get there, we are sure to make progress; for we can hold our own, watch events, plan and explore during the winter, and when the season of the next year opens, be ready. In the meantime we can be sending out these exploring sledging parties, of which Osborn speaks, to ascertain how the land lies; and after we have done that, and explored all that unknown region of North Greenland, then we can come back and know exactly how to plan our expedition by the Spitzbergen or any other water route. For such reasons I think the expedition should be sent in that direction, where the land is, and where we can

hold on to what we get; to be sure even this route—the Smith Sound—is not without its difficulties, even after a lodgment; still we are there, and can hold on to what we get. And being on *terra firma*, we will not be liable to be brought away again by the invisible influence of currents, without having accomplished anything. The other evening something was said at the Geographical Society about the habits of the whale, about whales always delighting in warm water. Now, there are two kinds of whale known to the fishermen, and which are their chief game. One kind is called the sperm whale, and the other is called the right whale, or the Greenland whale. One is a cold water animal, the other is a warm water animal. I have examined the log-books of thousands of whalers; I have divided the ocean out into fields; and I have marked, precisely as you mark wrecks on your wreck chart, where these vessels have searched for whales, and the number of times that they have seen whales in all parts of the ocean. In this process, the fact was brought out that the equatorial regions are to the right whale a sea of flame. The right whale has never been seen within the equatorial regions; they are the place for the sperm whales. In the extra-tropical regions of the south "right whales" are also found; but they are not the same as the "right whales" of the north. That these cold and warm water whales are different is shown by the fact that the fishermen go to Greenland and the North Pacific to look for the Greenland or right whales; and others go into the equatorial regions of the Pacific and Atlantic, to fish there for the sperm whale. This circumstance induced the query from me among the whalemen to know if the fish they called the right whale in the North Pacific was the same fish that they called the right whale in the South Pacific. The answer was, no; the South Pacific right whale, though resembling in general features that of the North, was a much smaller whale than the right whales of the north, neither are they as dark. Then the query was carried on further, to know whether the right whale of the North Pacific and the right whale of Greenland are the same fish. At last I came across a man who had fished in both seas, and he told me they were identically the same. Therefore, we came to the conclusion, that these right whales, since they could not cross the equator, had passed from one sea to the other through the Arctic regions. This was considered as a proof of the existence of open water in the Polar regions, because these whales are air breathing animals; they cannot live a long time under water; they must have an open sea to pass through and get breath. This evidence as to the existence of a water way between the Atlantic and Pacific through the Arctic Ocean, was further confirmed by the report that some time before, I cannot call to mind the year, a whale was taken in the North Pacific, just to the south of Behring's Straits; and when it was hauled alongside to be "cut in," there was taken out of it a harpoon that was known to belong to a ship that had fished in the Greenland seas some years before. Thus we had the first practical proof, from the whales themselves, that there is a water-way, at least at times, from one sea to the other, and this was afterwards fully confirmed by the bold, adventurous, and daring exploits of the British navy.

Rear-Admiral Sir EDWARD BELCHER, C.B.: I will begin by saying that I am certainly an advocate for the Spitzbergen route. The first point we have to consider is the difficulty of going north among these bergs. Unless you have a point on which the bergs rest, and where they are resisted, I am of opinion that there is no danger in boring through the ice in the free Arctic sea; therefore, the bugbear that we should be crushed or pressed in the Arctic regions by the ice we enter, is at an end. I believe I went into the ice in the smallest vessel that ever entered between icebergs. In Behring's Strait, in the deck boat of the "Blossom," I was for twenty days among icebergs, grounded in twenty fathoms water off Icy Cape; therefore, I know how easy it was for the "Investigator" to pass outside and among the ice grounded off the north coast; and Collinson himself proved how easy it was to travel in shore within the grounded ice. He got along by simply passing along inside the outer bergs that had grounded. It was found that the bergs generally, or rather the heavy ice in Maclure's Straits, formerly the continuous entrance from Barrow's Strait, is driven by a westerly current, caused by the innumerable islands which lie in that course, and which offer an opposition to the surface current. The under current presses so heavily that the ice in that region never can free itself, and never

can reach that open western space. But, on the other hand, when we get the Gulf stream setting past Iceland, through to Spitzbergen, and pressing along the whole north coast of Asia, that Gulf stream picks up all the drift-wood from Northern Asia, carries it along, and deposits it on the northern shores of America. The drift-wood must pass clearly round, and probably the whales that have been spoken of make that passage to the north, and we learn that similar drift-wood is found on the north coast of Spitzbergen; but I do not believe a single piece has yet been found on the eastern shores of Greenland. Now, I was two years in succession upon the Behring's Strait side, and among the drift-wood to which I allude. You may naturally ask, What is the nature of that drift-wood? What is it composed of? That drift-wood must come from rivers to the westward which run deeply into Asia, and you would naturally expect that it should prove to be pine and cedar. But we found all the harder woods, the finer woods; and the implements which I have obtained from the Esquimaux on the northern coast of America are made of beech, birch, Canada elm, and all those woods which come from the depths of the interior of the continent. They are not the mere pine trees that are drifted off. On one occasion I saw, and I believe I am the only person now living of that crew who ever saw a pine tree growing freely on the top of an iceberg. In Beecher's Voyage you will see a drawing and a description of that tree. It was adrift off Ice Cape, growing on an iceberg forty feet above the level of the sea. The tree was in all its beauty, with about eight or ten feet of soil attached to it. That tree must have come from some of the Northern regions, where it had been actually attached to the land virtually as a berg, and from which it had calved or broken off. It was a *bonâ fide* berg, with a living tree on it. That was one of my reasons for holding to the northern current. Where bergs float to, open spaces must exist, and the Gulf Stream, which passes by Spitzbergen and goes up along the coast of America, must have a cause for its continued action. I think that former voyagers, Scoresby and others, made a great mistake when they attempted to pass between Spitzbergen and Greenland. I will allow that Spitzbergen may be called an off-lying islet of Greenland. Then there may be a deep bay there, or a narrow pass, and down that narrow pass we naturally find all the bergs that have calved off the main berg of Greenland float down and pass round. They do not come down to the banks of Newfoundland, but round Cape Farewell, pass up Davis's Straits on the east, and back again down the western side. The ice that bothers us in Davis's Strait is the ice that thus goes up and back again in the eddy. It never can reach Newfoundland. Now, as an old cruizer off Newfoundland, I can state that we were always disturbed by icebergs in the month of April. They could not have drifted in that month, for the bergs are all frozen up hard and fast in the North, and it is only in the month of August when they begin to move from the north, and at that period the sea round Newfoundland is free from icebergs. The icebergs from the north never pass beyond the 46th parallel. They go round and meet the warmer waters of the Gulf Stream the tail of the Great Bank of Newfoundland, and there they dissolve Why do they dissolve?* They are missing in a night. They come down, passing over the bank, in a temperature of 38°.

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* To illustrate this, the Grinnell Expedition furnishes the following data:—

Lat.		Long.		Tempr. sea.
°		° ′		°
40 N.	.....	67·30 W.	.....	58
42	.....	61·30	.....	42
45	.....	59·0	.....	38
Off Cape Race	.....		shoal water	39
48	.....	52·0	among ice	36·5
53	.....	51·0	.....	38
58	.....	52·0	.....	41
60	Cape Farewell, Greenland	33·0	.....	38

The temperatures rise on losing soundings.

They meet on the banks a temperature of 46°, passing the 40th parallel perhaps at 60°, and that causes them to explode and disappear. If they pass the boundary of the banks they come into a temperature of 75°, and in a temperature of 75° the heat acting upon ice would cause it to disintegrate instantly, and fairly to explode; therefore, the assertion that icebergs come down that line will not bear any examination.* Now, if Spitzbergen be an off-lying group belonging to Greenland, and there be a channel between, for there must be something of the kind, some channel to allow those icebergs to come down. If it will not be admitted that there is a vacancy or open sea behind the icebergs as they move forward, it will be admitted that there must be a channel. Then, if there is a bay, there is a vacancy there; and if there be land it must reach out towards Spitzbergen. Now, if there be land and a bay there, I maintain you will find a better harbour to winter your ship in than you will in Smith Sound. I would say, place your ship in that harbour, and make your sledge journeys from it. But if you take your ship all the way round to Disco, you will have to stop there and lose one year's provisions. You may get up to Upernavik and be detained there, and then go up to Smith Sound, to find, as Inglefield did, that he could not get an inch further, and be obliged to come back again. It appears to me palpably ridiculous to try that route when the whole distance between the northern point of Spitzbergen and the Pole is simply 480 miles. Five miles an hour would be monstrous slow work for a steamer to push her way through the ice, and at that rate she would only be four days running to the Pole. Sledge rate is about fifteen miles a day. As to there being no land there, it looks nothing on the map, but there are 960 miles diameter from one side of the supposed Polar Sea to the other, on which you are to look for land, independently of the millions of acres that are beyond that circle. Parry went north, and left his ship behind him in Hecla Bay; but he had an observatory there, and officers watching during the 48 days that he was absent. The observations, which are printed, inform us that no ice was seen from the height of that glacier for 48 days. To show you how rapidly the ice parts, and how dangerous it is to sledge travelling, I started in the month of August from my ship, with three boats.† We experienced great difficulty. However, we got as far as Exmouth Island, and with my own boat to North Cornwall. But before this, while I was making my observations from the summit of Victoria Mount, I was warned that "the ice was coming," and that we should be nipped if I did not immediately rejoin the ship, and I was hurried down, rather against my will! There are gentlemen here who will tell you that I am not easily taken away from an instrument, particularly when looking at land that had not been seen before. If I had stayed one hour longer on Mount Victoria I saw that the ships would have been carried right into that sea, never after open, and I should have been literally fixed in the Arctic ocean. Subsequently, while I was at the summit of Exmouth Island, the whole space between us and the ship, which had been open water, about eight or ten miles in extent, and which I had passed over in my boat, became suddenly blocked in every direction as far as the eye could reach. In the course of half an hour, almost as if by magic, the ice opened and moved off. There was not an atom of heavy ice to be seen around me in any direction, and the land that was on the other side of me, eighteen miles north, was perfectly free from ice. I got into my boat, and made sail to that other island. When I got up there I watched the ice with anxiety, because it was only a little fragile boat the length of the table (12 feet), and there were six of us in it, besides tent, gear, and provisions. I was very anxious to get from that place back to Exmouth Island, and then back to the ship. I clearly saw a whole mass of

* We hear constantly of the "Spitzbergen ice" simply from bergs and floes coming from the north down the eastern extremity of Newfoundland; but if we reason on the distance between the southern point of Greenland, and the rate of drift as determined by Sir E. Parry, we find a direct course of S.W.¼W., and distance about 1,700 miles, which, at the rate of four miles a day, *against prevailing westerly gales*, would take 425 days to accomplish. When, then, I would ask, would it reach the banks of Newfoundland. E.B.

† One gig and two light runner or sledge boats.

ice which had been disrupted the day before all coming back with a westerly gale, travelling up to the eastward. I waited my time. I knew there would be a change at high water, and, as I expected, it moved again to the westward, and I made my escape; therefore, if you send any sledge expedition from Smith Sound you must make up your mind to meet with these lanes of water through the ice, and you must be provided with boats to pass those lanes of water. That was the difficulty which impeded Parry; it distressed his men. Ross was his constant companion, and subsequently a friend of mine, and he told me that when they gave up travelling over the ice they were so far reduced that it was with the greatest difficulty that they got their boat out of a hole. They had to unload her, and to get both crews together to pull her out. It was a narrow escape. Parry did not like to tell you exactly what he felt at the time, but I know that he felt it was a very great escape. With respect to the whales, I am glad that Captain Maury has set me right. One is the right whale, the other is the sperm whale; but they are so near each other in form, in anatomical structure and in their teeth, that unless he were a good whaler he would hardly be able to tell you the difference between a sperm whale and the other, except by the nose; but so far as structure goes, they are pretty nearly the same. I have seen the sperm whale to the northward of the river Columbia in the Pacific. That is pretty far north.* In the southern regions we have another power which acts more strongly than at the north. Those who travel from England to India know that in 60° south they go at a tremendous pace. The vessel which has been going only eight knots by reckoning through the water is frequently found to have passed much farther in space. There is a very rapid current setting always to the eastward. We have no such rapid current at all in the northern regions. The Arctic Sea, so far as we have data, up by Spitzbergen and that latitude, is never found below 38°. We recorded the temperatures during the voyage out and up to the south point of Greenland, and although it was said that wherever you could smell an iceberg you will have the thermometer at 32°, we found the temperature of the sea water during the whole time of our passage out was never below 38°. It suddenly became cold on our sighting Greenland, but not before. On the other side of America I have been close in off Mount St. Elias, where the thawed ice water was driving the bergs into the sea alongside of us; and the temperature of the sea-water there, though mixing with a great deal of fresh water, was never below 38°. The great advantage that I think we should derive by sending a steamer direct from Spitzbergen would be, first, you could establish a party at Spitzbergen who would be very usefully employed during the time that the vessels might be absent. The chances are that you have only 480 miles before you to play with, and you are almost certain of finding land of some sort if you pursue a course easterly of north, and the current runs as we suppose easterly. In all the communications which have been read by Admiral Ommanney we find the sea was open N.E. and E.N.E. The sea lies open in that direction, and, therefore, if you should adopt an easterly course and are also drifted by the Gulf Stream, I believe it even possible that you might be carried right round the Pole.

Mr. CLEMENTS MARKHAM, F.S.A., F.R.G.S.: I did not intend to have said a word to-night, because I am a strong advocate of the Smith Sound route. Two objections have been raised against it. One is the difficulty of getting up Baffin's Bay; the other is the danger of meeting open water during the season of sledge travelling. With regard to crossing Melville Bay, I think it will be enough to say that since the days of Baffin, exploring vessels have started to go up thirty-eight times. Thirty-six times they have succeeded, so you may discount the difficulty. Sir Edward Belcher's objection with regard to the difficulty of travelling on account of the ice moving about, and opening and closing, would apply if the travelling season was in February, or March, or April, but I think Sir Edward said that he was stopped by these movements of the ice in August; therefore, I do not see what it has to do with the period during which sledge travelling would take place.

Sir EDWARD BELCHER: I saw the open sea in May.

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* Since I have found, amongst the chatelaines of the Esquimaux women, *models* of *the sperm whale.*—E. B.

Mr. MARKHAM: In May it would be more awkward.

Captain INGLEFIELD, R.N., F.R.S.: Admiral Ommanney asked me to come here this evening to say a few words with reference to my views on this subject; therefore, I have great pleasure in seconding his opinions with reference to the route by Spitzbergen. I do so upon two grounds, principally on account of the great difficulties in getting through Baffin's Bay up to Smith Sound, and also with regard to the sledging after you have arrived at the northernmost point that your ship can get to. For let us suppose that you are able to put the vessel into some convenient harbour in Smith Sound, it has been admitted on all hands that there is great difficulty in carrying boats by sledges; and let us suppose that on sledging up the coast from the northernmost point that the ship has attained, you reach the open water which so many agree in believing to exist round the Pole, how, then, are you to proceed to the Pole? for it will be almost impossible to carry a boat any great distance, and you are far removed from your ship. But, on the other hand, if you leave England, reaching Spitzbergen, refit your ship at the highest latitude there, you may then sail through this *mare incognitum*, or unknown sea; and should you succeed in reaching land, you may then start with your sledges, and you have then advantages which you could not expect if your ship was far removed from your position. I am, therefore, strongly in favour of the route by Spitzbergen. After three voyages into Baffin's Bay, and after sailing into Smith Sound myself, it might be supposed that I would advocate that route, for I sailed into Smith Sound with a perfectly open sea, and there was no appearance of ice; but a gale setting in, we were driven to the southward, and I was obliged to give up the expedition into the Polar Sea. On two other voyages through Baffin's Bay I found the greatest difficulty in getting to Melville Bay. On the last occasion, when I brought home the officers and crews of the ships that were left out there, we failed altogether to get through Melville Bay. With these objections I think the Smith Sound route is one which should not be attempted, because there may be great doubt as to your succeeding at all in getting to Smith Sound to make any exploration of the Polar Sea, while, with Spitzbergen, I believe you have every chance of gaining your object of reaching the Pole.

The CHAIRMAN: As your Chairman, I am not permitted to take part in the discussion. Therefore, all I will do will be to recall your attention to one or two facts. First, you will all agree with me that there is a great difficulty in getting to the Pole. I would also say, that when you actually got there, you would have great difficulty in saying that you had got there; because you have no time, nothing to depend upon but your latitude. And I really believe that nobody ever could know when he got to the Pole, unless the magnetic pole had been on one side of it, for you will have to determine your position with the compass. I have been asked how it is that all you Polar gentlemen advocate this scheme? I really begin to think it is because we are all so accustomed to difficulties that we learn to take a pleasure in them, and to experience an enjoyment and a satisfaction in overcoming them. But I would say a word or two upon the great importance of these explorations to our country. You may say they are undertaken for scientific objects, but still they are of great national importance. Let us fall back upon that period when Drake, Raleigh, and Frobisher set on foot those great maritime discoveries, which have led so much to the extension of our commerce and to the promotion of maritime discovery. See how they have been carried on from age to age, and from time to time, until in this great and glorious reign of Queen Victoria we can see our ships sailing from sea to sea with speed and in safety. This is what has been done, and the work has descended to us as an heir-loom, and I would counsel the nation to maintain it. We know perfectly well that the result of that memorable voyage of Captain Cook, which was set forward solely for scientific objects, the observation of the transit of Venus, has been the acquisition to our Empire of two enormous Colonies that are now a source of splendour and prosperity to us. These are points that should be borne in our recollection. I maintain that it would be a token of our deterioration as a nation if we relinquished that principle of maritime discovery which has done so much for our country. It remains to me to ask you to return your thanks to Admiral Ommanney, who, at a very short notice, has given us an admirable exposition of what his ideas are upon this subject.

Evening Meeting.

Monday, April 24th, 1865.

REAR-ADMIRAL E. OMMANNEY in the Chair.

NAMES of MEMBERS who joined the Institution between the 3rd and 24th April, 1865.

LIFE.

Curling, J. B., Lieut. Roy. Engrs. 9*l.*
Halkett, J. Craigie, Capt. Highd. Borderers Mil. 9*l.*

ANNUAL.

Croker, Wm., Captain 27th Regt. 1*l.*
Brodigan, F., Lieut. 28th Regt. 1*l.*
Baily, T. F., Capt. Kent Art. Mil. 1*l.*
Bennett, W. C. F. B., Capt. 6th Regt. 1*l.*
Cumming, Wm., Captain 48th Regt. 1*l.*
Nicholetts, G., Capt., 27th or 1st Belooch Regt., 1*l.*
Hitchcock, H. J., Capt. 2nd Bat. 24th Regt. 1*l.*

ON THE MAGNETISM OF IRON AND IRON-CLAD SHIPS.

By FREDERICK J. EVANS, Staff-Commander R.N., F.R.S., Superintendent of Compass Department, H.M. Navy.

IN the Session of 1859, at the request of the Council of the United Service Institution, I contributed a paper on the "Magnetism of Ships," the purport of which was "to describe in as brief and popular a manner as the subject would admit of, the progress and present state of our knowledge of the magnetic condition of iron and wood-built ships, and the consequent effect on the mariner's compass." This paper will be found in the published Journal of the Institution of that year.

Again, at the request of the Council, to contribute an account of the recent additions to our knowledge of the same subject, I appear before you this evening, and although in the short time at my disposal

it will be only possible to touch on some of the more general points of the somewhat complicated problem of the effect of the iron of a ship, yet I hope to render intelligible the advances that have been made both in the theory and practice of this important question to the seaman.

Historically we may consider that there have been three stages in the investigation of the "deviation of the compass"—the first, which dates from the commencement of the present century, was that of wood-built ships, the second that of iron ships, and the third that of iron-plated ships of war. My former paper partially comprised the two first; subsequent additions to this branch of science were made in the period 1859–61, by the following works:—

"Journal of a Voyage to Australia, and round the World, for Magnetical Research." By the Rev. W. Scoresby, D.D. London, 1859.

"Reduction and discussion of the Deviation of the Compass observed on board of all the iron-built ships, and a selection of the wood-built steam-ships in H.M. Navy, and the iron steam-ship 'Great Eastern.'" By F. J. Evans, Master R.N., Superintendent of the Compass Department of H.M. Navy. (Phil. Trans. 1860.)

"Third Report of the Liverpool Compass Committee to the Board of Trade, 1861."

With this notice I pass at once to the third stage, offering alone such prefaratory remarks as are necessary for elucidation.

The introduction of armour-plating, and its application to both wood and iron hulls, combined with the general use of iron for decks and beams, shot proof transverse bulkheads, gun-turrets and iron lower masts, it was speedily found materially affected the problem of the correction of the deviation of the compass. Errors formerly taken into account were greatly increased, and errors and causes of error which formerly were safely neglected, became important, and the approximate mathematical formulæ alluded to by me in 1859, which were sufficiently exact for the then existing deviations, ceased to be applicable.

These changes led to a revision, or rather extension of the mathematical theory of the deviations of the compass and of the practical methods of ascertaining and applying the deviation. This revision, at the request of the Admiralty, was undertaken by Mr. Archibald Smith and myself, and are contained in the "Admiralty Manual for ascertaining and applying the Deviations of the Compass caused by the Iron in a Ship," published by the order of the Lords Commissioners of the Admiralty. London: Potter, 1862. 2nd edition, 1863.

The scope and design of this manual I will briefly place before you, observing that the whole is the result of much patient investigation, both experimental and theoretical, and of long practical experience. The work is divided into four parts, each part being complete as a distinct branch of the subject.

Part I. Contains the well-known practical rules drawn up originally in 1842, by a committee of distinguished naval and other men of science, among whom, and indeed the only one remaining to us, is the present President of the Royal Society, General Sabine.

These rules, which are purely practical, have undergone revision, and have been added to from time to time as theory and practice progressed.

Part 2. Is a description of the valuable graphic method known as "Napier's Method," in which the deviations of the compass are represented by the ordinates of a curve, of which the "courses" or "azimuths" of the ship's head, which correspond to the deviations, are the abscissæ. The practical advantages of the method are very great,—especially when dealing with the larger deviations of iron ships and with their ponderous hulls, which frequently cannot be steadied for the purposes of observation by hawsers,—as it enables us from observations of deviations made with the ship's head on any number of courses, whether equidistant or not, to construct a curve in which errors of observation are, as far as possible, mutually compensated, and which gives the deviation as well on the compass courses as the correct magnetic courses.

Part 3. Contains the practical application to this subject of mathematical formulæ derived from the fundamental equations deduced by M. Poisson from Coulomb's Theory of Magnetism, first given in the "Memoires de l'Institut," tom. v, page 533.*

Although the mathematical investigations from which these formulæ are derived can only be followed by the mathematician, yet the use of the formulæ, accompanied as they are by tabular forms and examples, may be as easily acquired as are the ordinary computations in the practice of navigation.

The formulæ, in addition to the five coefficients A, B, C, D, E, explained in my last paper, embrace expressions for separating and distinguishing the different parts of the deviation according to their respective causes, as, for example, separating the quadrantal deviation into the two constituents—that which arises from fore and aft induction, and that which arises from transverse induction. This separation has thrown great light on the cause of the quadrantal deviation, and consequently on the means of modifying its amount by the selection of a place for the compass. Expressions also are given of easy application for deducing the heeling error, from observations made on an even keel, and for separating the two parts of which it is composed.

In the second edition methods are introduced of determining the coefficients from observations of deviation and horizontal force made with the ship's head on *one* point; these furnish the means of approximately determining the deviations of a ship without swinging her, and while she is still on the stocks or on dock.

The importance of being thus able to detect the heeling error by observations of a simple kind, made with the ship upright, and of constructing an approximate table of deviations without swinging the

* Poisson's equations are derived from the hypothesis that the magnetism of the ship, except as far as it is permanent, is transiently induced, with an intensity proportional to that of the inducing force; and that the compass needle is of infinitesimal length compared to the distance of the nearest iron.—F. J. E.

ship, is unquestionable, and is one of the most practically useful of the results of the application of mathematical formulæ to this subject.

Part 4 of the manual treats briefly on Terrestrial Magnetism as connected with the deviation of the compass. It is accompanied by charts of the lines of equal magnetic variation, equal dip, and equal horizontal force. The first gives us the means of ascertaining the deviation of the compass by astronomical observations made at sea. The charts of the dip and horizontal force are useful as throwing light on the changes which the deviations undergo on a distant voyage, and as enabling the navigator further to anticipate the changes which necessarily take place on a change of geographical position.

The material assistance rendered by Mr. Archibald Smith to navigation by his simplified and clear mathematical treatment of the subject, is beyond my humble meed of praise; but it is a pleasure to bear confident testimony that in the manageable form to which Mr. Smith has reduced the exact formulæ necessary, they do most satisfactorily represent all observed phenomena. I hope that at the conclusion of this paper, that gentleman, who is present, will give to you some information connected with the subject which is not embraced in my communication.

The deviation of the compass on board ship, it is now well known, consists of three parts, namely, the "constant," the "semicircular," and the "quadrantal." Dismissing the constant part for the present from our consideration, both theory and observation distinctly prove that the whole deviation is composed of two parts, one of which (the semicircular) runs through all its values, both positive and negative, *once*, and the other (the quadrantal) *twice*, in a complete revolution of the ship. These parts have accordingly thus received their distinctive names. The semicircular deviation being easterly in one semicircle and westerly in the other, as the ship's head moves round a complete circle in azimuth. The quadrantal being easterly and westerly alternately, in the four quadrants, as the ship's head moves round the complete circle.

The distribution and amount of these two distinct errors of the compass in iron ships are very different from those in the wood-built ship; and this is a most important feature for the student to realize. The points of *no* semicircular deviation, sometimes called the neutral points, are opposite to each other, and the sine of the deviation in each semicircle is proportional to the sine of the azimuth of the ship's head, measured from the neutral points; in wood-built ships, the neutral points coincide nearly with the North and South points, and from the north end of the compass needle being drawn towards the bow, the deviation, when the ship's head is east, is (in northern latitudes) Easterly; and when the ship's head is west, Westerly. In iron-built ships, the points of no semicircular deviation approximate to those points of the compass to which the ship's head and stern were directed in building, and it follows that the deviation is Easterly when the *part of the ship which was south in building* is east; Westerly, when it is west. The iron ship built head north, has, in consequence, a curve of deviations opposite to the ship built head south, but both with the common feature of the

neutral points being at the North and South points; the same inversion of curves exists with ships built head east and west, but with the neutral points at the East and West points of the compass. In iron-built ships the amount is frequently found from 20° to 30°; in wood-built ships of war it seldom exceeds 10°.

The quadrantal deviation has its four zero points coinciding very nearly with the cardinal points. In iron ships it has the distinctive feature of *invariably*, in a compass ordinarily placed, being easterly in the N.E. and S.W. quadrants; westerly, in the N.W. and S.E. quadrants. In ordinary iron ships its amount ranges from 3° to 7°, but in some of the armour-plated ships, it amounts to 12° and 14° on the main deck, and $8\frac{1}{2}$° at the standard compass. In wood-built ships it is invariably small, and was thus unnoticed by our early navigators. The quadrantal deviation has also the remarkable property of remaining unchanged in all magnetic latitudes, and of being little changed by the lapse of time.

Part of the increase of deviation in iron-plated ships is the indirect result of a circumstance which has other more direct effects of a prejudicial character, namely the serious diminution of the directive force of the earth's magnetism on a compass surrounded on all sides by masses of soft iron.

Thus, for example, on the main deck of these ships it has been found only equal to ·725 of the earth's force, at the steering compass to ·760, and at the standard compass an average of ·800; this force in ordinary iron ships being about ·900, and in wood-built ordinary ships scarcely differing from the earth's force, or 1·000. The representative coefficient of the above (λ), or the ratio of the mean force to north at the place of the compass to the earth's horizontal force, has been determined in many classes of ships; indeed, observations of horizontal force have now become part of the regular series of observations made in ships in which its determination is of importance. The requisite formulæ will be found in the Admiralty Manual.

Another error of great importance has been brought into prominence in the modern class of iron-built ships, and is known as the "heeling error." It is found by experience that as the vessel heels over, the north end of the compass-needle is drawn either to the weather or lee side, generally the former in the northern hemisphere, and the deviation so produced, when the ship's head is near north or south, often exceeds the angle of heel. This not only produces a deviation which may cause a serious error in the ship's course when steering near those points of the compass, but, if the ship is rolling, produces a swinging of the compass-needle which may render the compass for the time useless. This error had been known to exist, and its amount had even been measured by heeling the ship in the case of H.M.S. "Recruit" (1846), "Bloodhound" (1847), "Sharpshooter" (1848), and in various cases recorded by the Liverpool Compass Committee (1855–61); but no method had been proposed for determining this error by observations made with the ship upright, and considerable obscurity was even supposed to rest on the causes and law of the deviation. The application of Poisson's formulæ has entirely removed the obscurity,

and furnishes an easy method of determining the heeling error by observations of vertical force made on one or more directions of the ship's head. These observations have likewise now become a regular part of the complete series of magnetic observations made in the principal iron ships of Her Majesty's Navy

The reduction of the several observations of deviation and horizontal and vertical force made in the armour-plated ships of Her Majesty's Navy, as they were severally prepared for sea, and at subsequent periods of their service, and also in certain iron-built ships of the Royal Navy, and of the Mercantile Marine, afforded such interesting results that Mr. Smith and myself felt justified in preparing a Report on the whole, which, by permission of the Lords Commissioners of the Admiralty, was presented to the Royal Society; this paper was read on the 16th March of the present year, and is now in course of publication in the "Philosophical Transactions."

The reduction gives the numerical values of the several parts of the deviation, viz., the "constant," the "semicircular," and the "quadrantal," of λ, of μ or the proportion of the vertical force on board to that on shore, of χ the heeling coefficient to windward; also of the several constituent parts of these coefficients.

The second part of this paper treats of the effect on the compass of masses of iron of various shapes, bearing some analogy to shapes for which the problem of the distribution of induced magnetism can be exactly solved, this includes such masses as solid shot, shell, tranverse beams and bulkheads, armour-plates, and iron tanks.

I now propose to lay before you some of the principal conclusions derived from the discussion of the numerical values.

Constant Deviation, *represented by the coefficient A in formulæ.*

When the compass is placed in the middle line of the ship, A may be considered as zero, having in fact little or no *real* value. An *apparent* value may, however, be given to A by index error in the compass on board, index or other error in the shore compass, or error in the assumed bearing of a distant object.

In compasses out of the middle line of a ship, or when the ship heels over, an A is frequently introduced, but it seldom exceeds 1 or $1\frac{1}{2}°$. A *real* value can only be caused by elongated masses of *soft* iron unsymmetrically arranged with reference to the compass, and would be the same in all parts of the globe.

Semicircular Deviation, *represented by the coefficients B and C of formulæ.*

On this there are four heads deserving special inquiry:—

1. On the original value and its connexion with the direction of the ship in building, and the position of the compass in the ship.

2. The changes which take place after launching.
3. The subsequent changes.
4. The changes which take place on a change of geographical position.

The remarkable law of the direction of the force causing the semicircular deviation in iron-built ships being dependent on their position in building, was established prior to the application of armour plates to ships of war. This law, provided the compass is free from the influence of individual masses of iron, may be thus expressed, "*the north point of the needle is attracted to that part of the ship which was south in building.*" The same law extends to the armour-plating of either iron or wood-built hulls; consequently we find that in those iron-built ships which have been plated after launching, and in a different position from that of building, that the direction of the semicircular force is generally intermediate between the two relative positions of the head in building and in plating.

These striking features are illustrated by a diagram annexed.

From these results we may infer that the process of plating an iron ship in the direction opposite to that of building will always produce a diminution,* and which in some cases may become a reversal of her semicircular deviation, and that by taking advantage of this circumstance the deviations of iron-plated ships may be brought within manageable limits.

As might have been anticipated, the amount of semicircular deviation in the iron-plated ships is large, more especially at the steering and main deck compasses; unfortunately, from the exigencies of the arrangements for fighting and working the ship, choice of position is very limited, and the deviations are larger than could be wished. At the standard compass an ordinary amount is 20°, at the steering and main deck compasses 25° to 30°, and recently, in the case of the "Minotaur," built head north, at the distance of 55 feet from the stern, the steering compasses had the enormous amount of 62°.

2. Immediately after launching, the semicircular deviation diminishes rapidly; one of the most instructive examples of this change was observed in 1859, in the "Great Eastern," by myself and Mr. Rundell, the secretary of the Liverpool Compass Committee. Circumstances were especially favourable for making the observations, and the results were really astounding. In the first five days there was a decrease of 12° on some points of the compass, in seven weeks of 19°, and in the first nine months of service afloat, it amounted to 32° 10′, or nearly three points.

* An interesting memoir on the "Magnetic character of the Iron-built Armour-plated Battery, 'Pervenetz,' of the Imperial Russian Navy," by Captain Belavenetz, R. I. N., communicated by Archibald Smith, M.A., F.R.S., will be found in the Proceedings of the Royal Society, April 27, 1865.

In this ship, built at Blackwall, advantage was taken on her removal to the Victoria Docks of the armour-plating being attached with the ship's head placed in a direction nearly opposite to that while building. The diminution of the ship's magnetic force is very remarkable during the process of plating.—F. J. E.

Changes of the same character, though not so great in amount, have been observed in the "Achilles," (the only example of a ship built and plated in the same dock), and also in the wood-built iron-plated ships. In all cases, except when the ship has been built nearly north and south, the relative changes of C, or that part due to tranverse magnetic forces in the ship, is greater than in those of B, when the magnetic forces act in a fore and aft line.

This points to the necessity of newly-built iron ships being most vigilantly looked after, and their compass deviation tables constantly verified during the first twelvemonth of sea service.

3. After a certain time, which may be roughly estimated at a year after launching—the ship being supposed to have undergone a fair amount of sea service—the values of B and C remain remarkably permanent, notwithstanding the strains arising from docking, gales of wind, and especially from the concussions arising from the drilling and firing of heavy guns.

A striking example of the permanency of the magnetism of an "old" or well-seasoned iron ship after severe concussion is afforded in the case of the "Adventure," troop-ship, built in 1854. This ship, in the course of foreign service, struck on a rock during a fog with sufficient force to tear away and crush in 20 feet of the stem and bow under water; observations for deviation and horizontal force were made *before* proceeding on the foreign service, and *after* the injuries sustained had been repaired in dock; these observations made with every accuracy failed to denote any change.

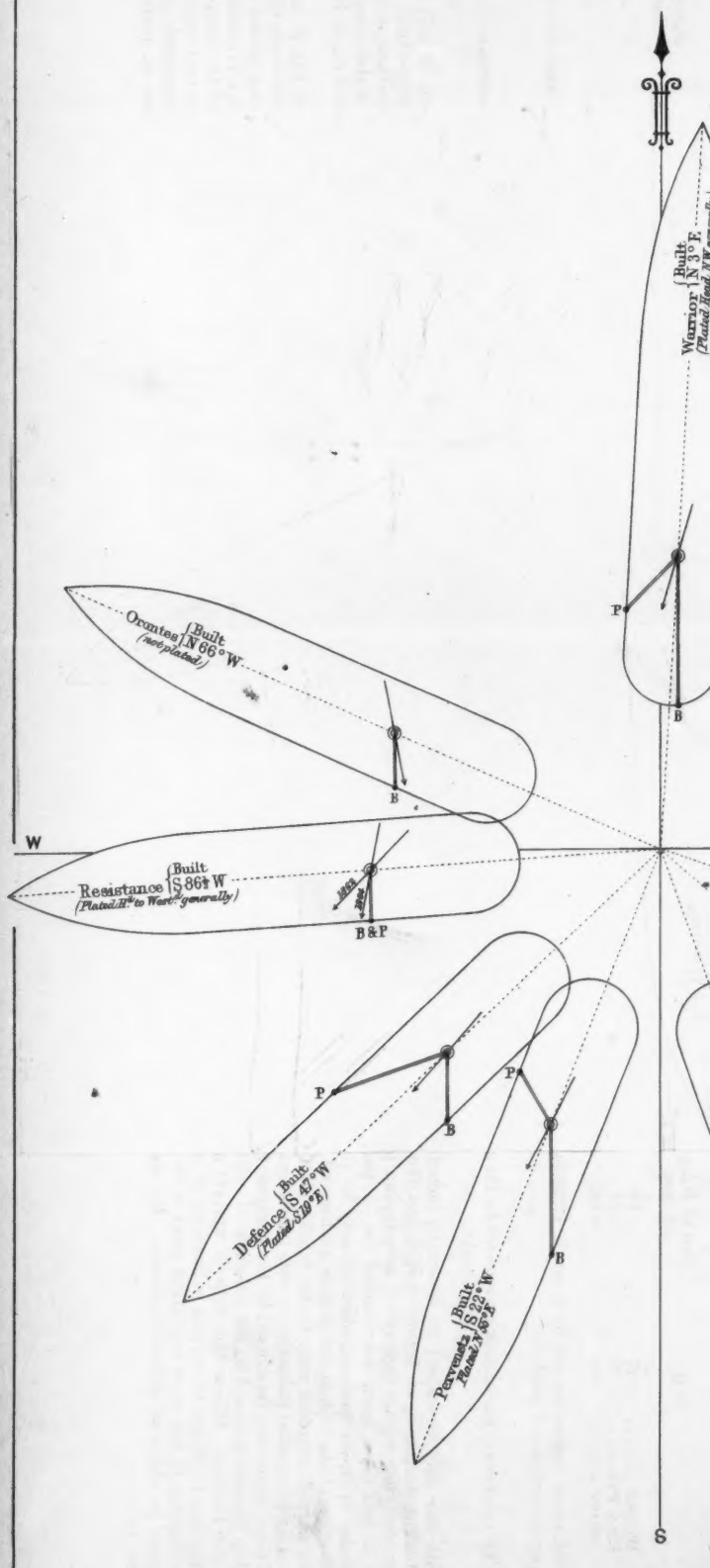
4. The changes which take place on a change of geographic position remains yet one of the most important questions for consideration. The permanency of the magnetism of many iron ships is very remarkable, and we judge of this fact by their semicircular deviation being found, in different parts of the globe, to be inversely proportional to the earth's horizontal force, as also that their deviations do not vary when swung in the same geographical position.

I will here pause for a moment to consider how the parts of the semicircular deviation are theoretically treated.

B is the principal coefficient, being the maximum amount of forces acting in a fore and aft line in the ship, and is therefore due to the principal masses of iron in the ship's equipment. It is composed of two parts; one arising from vertical induction in soft iron, and the other from permanent or fixed magnetism in the hard iron of the ship; these two parts have widely different proportions on great changes of magnetic latitude, as the first varies as the tangent of the dip, and the second inversely as the horizontal force.

[Assuming for example the ship to have changed her position from the English Channel to the Cape of Good Hope, the tangents of the dip of these two localities vary from + 2·5 to − 1·5, while the horizontal force varies only in the proportion of 1·0 to 1·2. The part of B arising from vertical induction in soft iron therefore varies in the proportion of 4·0 to 0·17, or as nearly 20 to 1 in excess of that part due to the permanent magnetism.]

C is the coefficient representing the maximum amount of forces

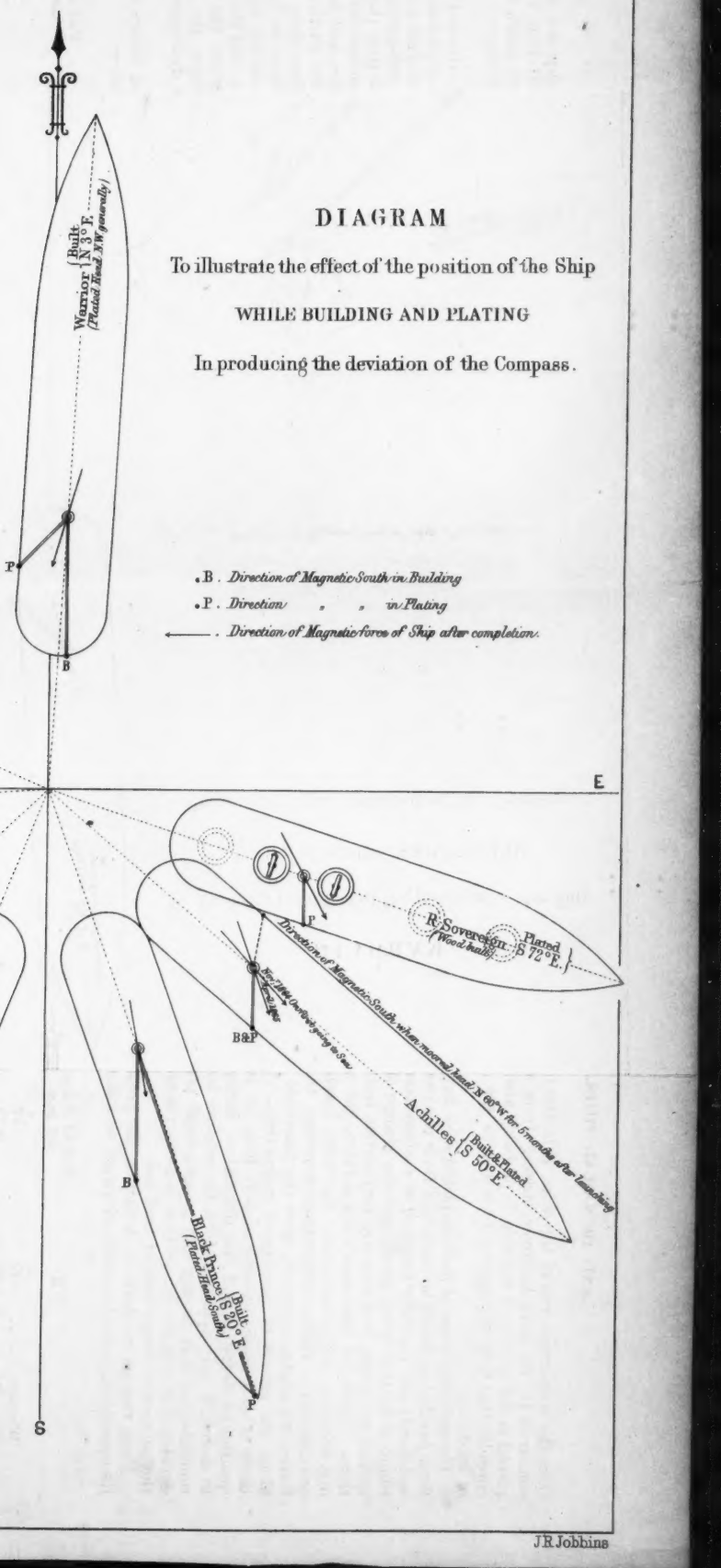

Warrior {Built N 3° E
(Plated Head W
P
B
Orontes {Built N 66° W
(not plated)
B
W
Resistance {Built S 86½ W
(Plated H^d to Ward generally)
B&P
P
B
Defence {Built S 42° W
(Plated S 39° E)
P
B
Perseverance {Built S 22° W
Plated N 67½
S

DIAGRAM

To illustrate the effect of the position of the Ship

WHILE BUILDING AND PLATING

In producing the deviation of the Compass.


Warrior Built (N 3° E (Plated Head N.W generally)
P
B
B. Direction of Magnetic South in Building
P. Direction " " in Plating
Direction of Magnetic forces of Ship after completion
E
R. Sovereign (Wood built) Plated S 72° E.
P
Direction of Magnetic South when moored head N or W for 6 months after launching
B&P
Achilles Built & Plated S 50° E
B
Black Prince Built S 20° E (Plated Head South)
P
S

J.R.Jobbins

from the transverse iron of the ship; it is also composed of two parts similar to B; the part, however, arising from soft iron, at a compass placed in the middle of the ship, is probably always small, and we may consider that C in the aggregate is due to the permanent magnetism of hard iron.

The cruizes of some of the iron-plated ships have extended to about the 30th parallel of North latitude, and their compass deviations have been sedulously and carefully obtained at various intermediate ports, but the range of latitude is too small, and the change of sub-permanent magnetism too great, to derive any very certain results from these observations. After the first year's sea service, the semicircular deviations are, however, very constant for the same localities, and have an approximation to values inversely proportional to the earth's horizontal force; we might, therefore, draw the inference that these results are alone the effects of permanent magnetism. There is, however, in these ships a large quantity of soft iron, as is shewn by the large quadrantal deviation and the diminished factor λ, and it is important to define, if only approximately, the relation between the two parts; remembering that in any one geographical position, the magnetism developed in soft iron by vertical induction is not distinguishable from the permanent magnetism of hard iron.

From various methods of deduction the present values of B and of its constituent parts in certain ships are as follows:—

	B.	Part of B from soft iron.	Part of B from hard iron.
	°	°	°
Warrior.....	−17	+12	−29
Black Prince....	+19	+23	− 4
Defence.....	+21	+14¼	+ 6¾

With these values we are by a simple formula enabled to compute B for any geographical position.

Quadrantal Deviation *represented by the coefficients D and E of formulæ.*

This can only be caused by *horizontal* induction in soft iron. The quadrantal deviation, as before stated, has the remarkable character of not changing with a change of geographic position; when, therefore, it has once been ascertained for a particular compass in a particular spot, its unchangeableness may be relied on so long as the distribution of the iron in the ship is unchanged.

The part E requires only to be briefly alluded to; it can only be caused by horizontal induction in soft iron *unsymmetrically* distributed; an E may, therefore, be caused by the compass being placed out of the midship line and exposed to the influence of cylindrical masses, such as iron gun turrets. When the ship is upright and the compass in the midship line there are no certain indications of any real value.

As regards D, the most important point is its magnitude in different positions in ships of different classes. Its cause is, perhaps, most

simply explained by conceiving rods of soft iron to be arranged according to one or other of the following types :—

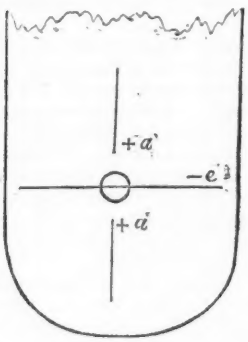


Fig. 1.

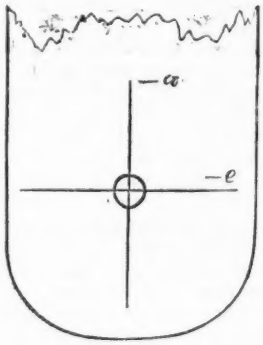


Fig. 2.

In these figures + a represents masses of iron directly before or abaft the compass, such as engines, boilers, funnels, and iron masts; − a represents soft iron extending through the position of the compass, such as the keel and hull of the ship, armour-plating, the screw-shaft, &c.; the effect of these last arrangements, in almost all cases, exceed the first, so that a is in general negative.

− e represents the effects of all the transverse soft iron, such as the bottom of the ship, the iron decks and deck beams, &c. + e would represent the masses of iron, comparatively few in number, which lie to one side of the compass, such as guns, boats, davits, &c. In every iron ship which has been examined, the effect of the transverse iron extending through the position of the compass exceeds that of any masses of iron wholly on one side, and thus e is negative in sign and greater than a.

The average value of D has greatly increased in modern iron ships, in their early days 2° to 3° would represent an average value; with the increase of horizontal iron in the fittings it is now generally 4° to 6°, and in the iron-cased ships, under certain conditions, it is found extending to 14° and 15°. This is shown in various classes of ships in the following table :—

	Warrior.	Black Prince.	Achilles.	Defence.	Hector.	Royal Oak.
	° ′	° ′	° ′	° ′	° ′	° ′
Standard compass ..	+ 8 27	+ 7 38	+ 6 58	+ 7 0	+5 24	+3 9
Starboard steering ..	+11 56	+10 32	+ 8 51	+10 16	+8 24	+1 47
Main deck	+11 43	+13 16	+12 13	+14 35	+9 47	+1 28

In order to see the nature of the disturbing causes we must obtain separately the two parts of the quadrantal deviation D, or the values of a and e.

Compass.		Warrior.	Black Prince.	Achilles.	Defence.	Hector.	Royal Oak.
		° ′	° ′	° ′	° ′	° ′	° ′
Standard	from fore and aft induction...	+ 0 06	− 4 04	− 2 45	− 2 42	− 3 51	−1 19
	from transverse induction...	+ 8 24	+11 42	+ 9 40	+ 9 44	+ 9 15	+4 32
Starboard steering	from fore and aft induction...	+ 0 14	− 3 47	− 3 47	− 2 17	− 3 23	−2 07
	from transverse induction...	+11 46	+14 28	+12 43	+12 35	+11 49	+3 51
Main deck	from fore and aft induction...		− 2 35	− 3 9	− 2 10	− 5 58	−3 51
	from transverse induction...		+15 58	+15 36	+16 58	+15 54	+5 20
Standard	a	+·002	−·112	−·079	−·078	−·109	−·043
	e	−·256	−·322	−·277	−·278	−·263	−·143
Starboard steering	a	+·006	−·100	−·103	−·064	−·093	−·066
	e	−·340	−·380	−·343	−·348	−·325	−·122
Main deck	a		−·063	−·083	−·048	−·151	−·116
	e		−·418	−·407	−·434	−·397	−·160

It is here obvious from the large values of $-e$, compared with those of a, that the resulting deviation is caused by the repulsion of the *north end* of the needle *from* the north *side* of the ship, being in excess of the repulsion of the needle from the north *end* of the ship; it being remembered that $+a$ would indicate an *attraction* to the north end of the ship, and $-a$, a *repulsion from* the north end of the ship.

It might appear from this that the repulsion from the sides of the ships, given as examples, was chiefly due to the armour-plates; but a comparison of the effect of these iron plates on a wood hull and on an iron hull separately, points to the conclusion that the larger amount of quadrantal deviation in the iron-built ship is attributable to the increased amount of transverse iron in decks, bulkheads, iron beams, and the iron bottom of the ship; the magnetism of which is, as it were, conducted upwards by the iron sides.

For the purpose of illustration, we may take the "Hector," iron-built, and "Royal Oak," wood-built ship, as types of the two ships which, from their arrangements of armour-plating and relative position of compasses, are directly comparable.

	Standard.		Starboard steering		Main deck.	
	a	e	a	e	a	e
Hector, iron-built	−·109	−·263	−·093	−·325	−·151	−·397
Royal Oak, wood-built with iron upper deck and supporting beams.....	−·043	−·143	−·066	−·122	−·116	−·160

In the wood ship the repulsion *from* the north side of the ship, or from the armour-plates, together with one iron deck and supporting iron beams, amounts to an average value for e of $-$ ·142, or an equivalent of $+ 4\frac{1}{2}°$ of quadrantal deviation. In the iron ship a similar average value for $e = -$·328, or an equivalent of $+ 12\frac{1}{3}°$ quadrantal deviation; the excess of nearly 8° is, consequently, due in the latter to the second iron deck, the transverse bulkheads, and the iron sides and bottom of the hull.

Some obscurity has hitherto existed as to the sources of the quadrantal deviation. It has now been traced as the resultant of two forces, acting either in conjunction or opposition, but almost always the latter in the modern iron-built ships, according to the arrangement

of the iron and the relative position of the compass—a general law prevailing in ships of similar types.

Allusion has been made to the prejudicial effect caused by the soft iron diminishing the mean directive force of the needle and so indirectly increasing the effect of all disturbing forces, as shown by the coefficient λ.

The cause of this diminution will be seen by the Figs. 1 and 2.

In Fig. 2, a little consideration will show that both $-a$ and $-e$ diminish the directive force. In Fig. 1, $+a$ increases the directive force, $-e$ diminishes it; but as $-e$ always exceeds $+a$, the result is a diminution on the whole.

We thus see that the value of λ is closely connected with that of D,—for algebraically expressed,

$$\lambda = 1 + \frac{a + e}{2}$$

$$\text{and } D = \frac{a - e}{2\lambda},$$

and we may, therefore, consider them together.

It has been a special object of inquiry to determine the value of λ in various classes of ships, and in various parts of the same ship. The importance of this coefficient was clearly perceived by the Astronomer Royal in his early and well known magnetic experiments in iron-built ships (Phil. Trans. 1839), he terms it the prejudicial constant M; [in the notation adopted here, $\lambda = 1 - M$].

In the earlier built iron vessels λ was very nearly equal to 1. In the "Rainbow" (1838) at four stations distributed along nearly the whole length of the ship it ranged from ·972 to 1·003. In the "Ironsides" the first sailing ship it was ·917 at the binnacle. In several iron-built ships purchased into the Royal Navy from 10 to 15 years after the Astronomer Royal's observations, λ at present averages about ·930. In the iron-plated ships of the present day it ranges from ·700 to ·900.

The following are its values in some of the iron-plated ships :—

	Warrior.	Black Prince.	Achilles.	Defence.	Hector.	Royal Oak.
Standard compass ..	·873	·783	·822	·822	·814	·907
Starboard steering ..	·833	·760	·777	·794	·791	·906
Main deck		·757	·755	·759	·726	·862

A very remarkable feature in λ and D is the change which takes place with the lapse of time, indicating apparently a change in the molecular structure of the soft iron, by which it becomes less susceptible of induced magnetism. Whether this change is accompanied by any change which can affect the strength, the liability to oxidation, or any other qualities of the iron are questions yet undetermined.

The annexed tabular values illustrate these remarkable facts.

			Standard Compass.		Starboard steering Compass.		Main deck Compass.	
			λ	D	λ	D	λ	D
Achilles ..	October	1864	·822	+ ·121	·777	+ ·154	·755	+ ·214
	December	1864	·854	+ ·116	·819	+ ·137	·804	+ ·188
Black Prince	November	1861	·716	+ ·145				
	September	1862	·783	+ ·134	·760	+ ·184		
	April	1864	·846	+ ·137				
	November	1864	·849	+ ·122	·881	+ ·144		
Defence ..	February	1862	·822	+ ·122	·794	+ ·179	·759	+ ·254
	December	1863	·853	+ ·122	·842	+ ·180	·810	+ ·230
	April	1864	·857	+ ·112	·853	+ ·159	·828	+ ·233
	October	1864	·852	+ ·112	·830		·842	+ ·230
Resistance..	August	1862	·758	+ ·111			·782	+ ·244
	December	1863	·850	+ ·122			·880	+ ·219
Royal Oak.. (*wood built*)	March	1863	·861	+ ·047				
	April	1863	·907	+ ·061	·887	+ ·067		
	June	1863	·907	+ ·055	·906	+ ·031		

Heeling Error.

The coefficients we have passed in review are those alone which affect the compass when the ship is upright; when the ship heels over, new disturbing forces are called into play, which we may consider as caused by arrangements of soft or hard iron of one or other of the following types.

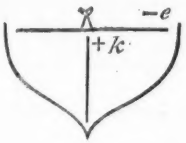


Fig. 3.

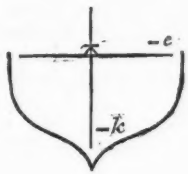


Fig. 4.

$-e$, represents, as before, transverse soft iron, which as the ship heels over, will evidently produce a force to the high side of the ship, or to windward, on the north end of the needle. If the rods $+k$ and $-k$ represents soft iron, then $+k$ gives a force acting downwards on the north end of the needle, which as the ship heels, becomes a force to windward; $-k$ a force acting upwards, which, as the ship heels becomes a force to leeward.

The permanent magnetism of the ship will generally act downwards if the compass is over the end which has been south in building, upwards if over the end which has been north in building. It follows that those ships built head north will have a large heeling

error in compasses *near the stern*, and a smaller one in compasses near the bow, and that the converse exists in ships built head south.

The heeling coefficient it will thus be seen depends partly on vertical induction in transverse iron, and partly on the mean vertical force arising from permanent magnetism and vertical induction in vertical iron; the two therefore conspire together when the vertical force of the ship acts downwards, and counteract each other when the vertical force acts upwards; and hence the great differences in the heeling coefficients of different ships.

Appended is a table of the results obtained in several ships. What is striking, is the uniformity of the heeling part from transverse iron, and in all ships, as might be expected, it is of the same sign; the differences are nearly all in the part which arises from vertical force, varying from + 1° 6′ in the "Warrior" to 1° 9′ in the "Enterprise."

In the wood built iron-plated ships, the vertical force is generally diminished, this is doubtless the effect of the armour-plating, which acts as a $- k$. Indeed in all iron-plated ships, whether wood or iron-built, the effect may be considered the same, and that the heeling error is probably diminished and not increased by the effect of the iron plating; for we find that when observations for heeling error have been made at the main deck compasses, the value is small and to leeward.

For convenience in investigation, and also for application in practice, the heeling error is measured by degrees and parts of a degree, as produced by every degree of heel when the *ship's head is north or south by the disturbed compass, as it is then at the maximum;—vanishing when the ship's head is east or west by the disturbed compass.* It is scarcely necessary to remark that the knowledge of this simple law is highly important in the navigation of iron ships, and is explanatory of the unlooked-for errors frequently found in the ship's reckoning when steering on courses near a meridional direction, such for example as from off the coast of Portugal towards Ushant, and up the Irish Channel.

Class of Ship.	Date.	Name of Ship.	Direction of Head in building.	Whole heeling* amount to windward. (For 1° of heel. ship's head N. or S.)	Amount arising from	
					Vertical induction in transverse iron	Vertical force and induction in vertical iron.
				° ′	° ′	° ′
Iron ships, iron-plated.	July 1862.	Warrior	N. 3° E.	+1 49	+0 43	+1 06
	Jan. 1863.	„ *Lisbon*		+1 22	+0 32	+0 50
	Sept. 1862.	Black Prince	S. 20° E.	+0 50	+1 01	−0 11
	Jan. 1863.	„ *Lisbon*		+0 52	+0 43	+0 09
	April 1864.	„		+0 43	+0 48	−0 05
	Oct. 1864.	Achilles (Standard aft)	S. 51° 40′ E.	+0 27	+0 50	−0 23
	Dec. 1864.	„		+0 25	+0 43	−0 18
	Oct. 1864.	„ (Standard forward)		+1 29	+0 49	+0 40
	Dec. 1864.	„		+1 18	+0 37	+0 41
	Feb. 1862.	Defence	S. 47° W.	+0 59	+0 51	+0 08
	Jan. 1863.	„ *Lisbon*		+0 30	+0 33	−0 03
	April 1864.	„		+0 36	+0 42	−0 06
	Aug. 1862.	Resistance	S. 86½° W	+1 18	+1 04	+0 14
	Dec. 1863.	„		+0 53	+0 45	+0 08
	Feb. 1864.	Hector	S. 20° E.	+0 45	+0 48	−0 03
	Jan. 1865.	Valiant	S. 87° W.	+0 48	+0 37	+0 11
Wood ships, iron-plated.	April 1863.	Royal Oak	Plated S. 49° E.	+0 07	+0 24	−0 17
	June 1863.	„		+0 04	+0 23	−0 19
	Feb. 1864.	Prince Consort	Plated S. 39° W.	−0 08	+0 16	−0 24
	Aug. 1864.	Ocean	Plated S. 79° E.	−0 15	+0 19	−0 34
	June 1864.	Enterprise (Iron topsides)	Built and plated S 56.°W.	−0 29	+0 37	−1 09
Iron ships.	July 1863.	Orontes	N. 66° W.	+1 04	+0 36	+0 28
	Nov. 1863.	Tamar	West	+0 51	+0 31	+0 20
		„ (Binnacle over rudder)		+1 10	+0 28	+0 42
	Sept. 1863.	Wye	Probably to E.S.E.	+1 0	+0 27	+0 34
	Feb. 1863.	Caradoc	Probably to N. by W.	+0 15	+0 14	+0 01
	Feb. 1863.	Clyde	Probably to N.E.	+1 22	+0 35	+0 47
	Mar. 1863.	Industry	Probably to S. by E.	−0 05	+0 18	−0 23
	June 1863.	City of Sydney	Probably to W.N.W.	+1 31	+0 46	+0 45

* − sign denotes a heeling error to leeward.

The principal conclusions to be drawn from the application of observation and theory to the magnetic phenomena in iron ships may be considered as follows:

1. The original semicircular deviation depends principally on the direction of the ship's head in building, and consists principally in an attraction of the north point of the needle to the part of the ship which was south in building. This attraction is caused by the sub-permanent magnetism induced in the ship when building by the horizontal force of the earth.

A residual part of the semicircular deviation is independent of the direction of the ship in building. It is the effect of the sub-permanent and transient magnetism induced in the ship by the vertical force of the earth, and it consists in an attraction of the north point of the needle to the bow or stern. In the usual place of the standard compass, this part is in the northern hemisphere an attraction towards the bow; but if the compass is placed nearly in front of a large vertical mass of iron, as the stern-post, it may be towards the stern.

2. The principal part of the semicircular deviation diminishes rapidly after the ship has been launched; but after a time, which may be taken roughly as a year, if the ship has been allowed to swing on all azimuths, it attains a very fixed and permanent amount, from which it does not afterwards vary to any great extent. The smaller residual part changes little, if at all, so long as the ship remains in the same latitude.

3. The changes which take place in the semicircular deviation of a ship built east and west, are generally relatively greater than in one built north and south.

4. The effect of the magnetism induced by the horizontal force when the ship is on the stocks is principally (and if the ship is built on a cardinal point, entirely), to produce a diminution of the directive force on the needle, and very little (and if built on a cardinal point not at all) to produce deviation. The same effect—nearly—is produced at a subsequent time if the ship's head is placed in the direction in which it was while building.

This diminution of the directive force is greater if the ship has been built east and west, than if built north and south.

5. The diminution of the mean directive force is the mean of the diminution caused by the transient magnetism induced by the horizontal force of the earth when the ship's head is north or south, and that induced when her head is east or west, that is, it is the mean of the thrust from the north *end* and from the north *side* of the ship.

6. The quadrantal deviation is caused by the excess of the latter over the former, that is by the excess of the thrust from the north *side* of the ship, over the thrust from the north *end*.

7. The diminution of the directive force and the amount of the quadrantal deviation are nearly the same at the same level in different parts of the ship. They increase in descending from the position of the standard compass to the steering and main deck compasses.

8. The diminution of the directive force and the quadrantal deviation both diminish with the lapse of time.

9. When a ship has been built head north, the upper part of the stern and the lower part of the bow are strongly magnetized, the upper part of the bow and the lower part of the stern are weakly magnetized. When a ship has been built head south, the upper part of the bow and the lower part of the stern are strongly, the upper part of the stern and the lower part of the bow are weakly, magnetized. Consequently in ships built head north, a compass placed near the stern will have a large semicircular deviation; there will also be a large downward force on the north point of the needle which will produce a large heeling error. In ships built head south, with a compass similarly placed, both the last errors will probably be small.

10. On the whole, for compasses to be placed in the after part of the ship, the best direction for building is head south. For compasses near the centre of the ship the directions head north and head south are nearly equally good.

I have now sketched the most striking features in the magnetism of the modern iron ship; but the matter would be incomplete without allusion to what has been done to modify the larger class of errors.

It is obvious that when the magnetic force of the ship is in antagonism to the force of the earth (which must be the case whenever the ship's head approximates to the direction in which it was when on the stocks) the compass-needle loses its directive force proportionally to the amount of deviation; for example, at the steering compasses of the "Minotaur," with 62° deviation, ship's head north, there would be only one-tenth of the earth directive force acting on the needle, and even this reduced value would be further diminished one-fifth by the mean loss of directive force due to the soft iron of the ship.

To remedy evils of this magnitude, compensation by permanent magnets on the Astronomer Royal's early-suggested plan becomes indispensable to equalise the directive power on all points of the compass; it has, accordingly, been adopted in several of the iron-clad ships.

The heeling errors of some of the more exaggerated cases have also been modified by the introduction of a vertical magnet placed directly under the centre of the compass; with our present experience this promises to be a simple operation to carry out in practice, and will be very useful, if only to stop the inconvenient oscillation due to magnetic causes when the ship rolls.

In my former remarks at this Institution, I placed fully before you the nature of the controversial opinions that existed on the subject of magnet correction; changes of circumstances necessarily have modified the opinions of those antagonistic to its adoption. I may be permitted to state my own opinions as running generally in accordance with those who are adverse to the use of magnets under all and every circumstance.

Another generation of navigators will possibly have acquired a sufficient knowledge of the laws of magnetism, and the variety of

conditions on board an iron ship, so to manipulate magnets as to render the compass correct at all times and in all places; but at the present time this knowledge is extremely limited, and I confess to hesitate the placing of so dangerous a tool as a moveable magnet in the hands of the untrained navigator. My views are now rather to place it beyond his reach; first attending to his convenience by reducing the larger errors within easy and effective limits—the residual errors to be constantly determined by observations of celestial bodies—and then securing the magnet as a part of the ship, in order that accident or design cannot disturb the effect, it being always understood that every precaution is taken to secure a position for the compass free from the effect of individual masses of vertical iron.

These brief comments on magnet correction lead to another point worthy of a moment's notice. When great evils affect us we are prone to seek any remedy to alleviate them. The troubles and anxieties attending erroneous compass action have produced a plentiful supply of professed remedies, prominent among which is that of cutting off the effect of the iron of the ship by some electrical or non-conducting medium; patrons to these schemes are found, and the minds of the many are diverted from the true direction, which should be study and observation of the subject.

I need scarcely say that all the schemes I have alluded to are chimerical, and on simple grounds; for if we cut off the effect of the disturbing cause in the ship, we are also cutting off the main supply, namely, the magnetism of the earth, which alone gives directive power to the needle.

In concluding this review of the joint labours of Mr. Archibald Smith and myself, extending now over several years, it may not be deemed presumptuous in me to draw the attention of the Institution to one feature of the subject which has forcibly presented itself in the course of our investigations.

The increasing number of our iron and iron-plated ships of war, with the actual and impending changes in the construction of wood-built ships, is assuming such magnitude, that the security of the navigation of these ships in relation to the action of the mariner's compass has become a question deserving more general consideration from the naval profession.

The art of navigation, under this changed condition of the substitution of iron for wood in ship-building, it is already found requires to be treated on broader principles than was formerly necessary, and must include a general knowledge of the elements of magnetism both in its practical application and in its general features, as one of the great forces of nature, so potent in its effects as far as relates to navigation, over the whole terrestrial globe.

That the great changes from wood to iron in the construction of the ships of all nations are bringing this change in their train, appears among other things from this, that within the last four years France and Russia have sent special agents to this country to acquire complete information as to the "compass system" pursued both in the

royal and mercantile navies, and as to the theoretical results obtained by the various investigators of this branch of science. This has led, in France, to the publication by the Minister of Marine of a special report, and also of the "Cours de Regulation des Compas professé a l'ecole du Genie Maritime" both by M. Darondeau, Ingenieur Hydrographe de la Marine; the latter work incorporates the most important parts of the Admiralty Manual. In Russia, to a translation of the Admiralty Manual, with notes, by Captain Belavenetz, of the Imperial Navy. In Austria, to a translation of the chief parts of the Admiralty Manual, by Dr. Schaub, Chief of the Imperial Hydrographic Academy at Trieste.

It is gratifying to observe that both in the theoretical and practical treatment of this peculiar branch of nautical science, this country has been looked to for instruction, and is still probably in advance of other nations. But it must not be forgotten that this knowledge is confined to very few of our Officers, arising chiefly from the rapid growth of the science having outstripped the provisions made for its general diffusion, and possibly, in some degree, from the growing importance of the subject not having hitherto been sufficiently set before them.

It is, however, necessary to observe that the practical determination by observations, and application of the deviation of the compass to courses and bearings are now fairly established and recognised in the naval service, and will, of course, be more appreciated as iron and iron-clad ships increase.

Little more, perhaps, can be done on this head than is done at present, but a wider acquaintance with leading general theoretical principles is an important supplement to the knowledge of practical details; and, indeed, that magnetism, in its application and connexion with the mariner's compass, must be deemed in a system of nautical education to deserve attention in common with nautical astronomy and other collateral subjects.

The CHAIRMAN: Gentlemen, I am quite sure that the thanks of this meeting are due to Captain Evans, for his able paper. I am sure that the information that has been given to this Society is very valuable. The paper displays a great deal of labour and care, and especially in regard to one or two important features for future instruction in relation to the compass, and which I hope will be attended to, as for instance that of heeling, a feature which requires to be more generally understood.

Mr. ARCHIBALD SMITH: I have been requested by my friend Captain Evans, to add to the interesting paper which he has just read to you a short account of some of the results of recent investigations in which we have been engaged into the effect of particular masses of soft iron in a ship on the compass. These effects are much more prominent in the case of modern armour-plated ships than in the case of the older iron-built ships. In the modern ships you cannot escape from masses of iron, and hitherto no care has been taken in the construction of ships to prepare a place for the standard compass. I hope the time is not far distant when it will be considered quite as important to prepare a place for the standard compass as for the main mast; but that time has not yet come, and when my friend Captain Evans has to select a place for the position of the standard compass, he has to consider the effect of all the neighbouring masses of iron, and select a place at which the effect may be as small and as regular as possible. Hence at present the great importance of being able to estimate approximately the effect of particular masses. I must apologise for introducing here some theoretical considerations, but without them it is hardly possible

to speak, or even think of the effect of the masses in question. I must explain in the first place that I do not propose to speak of what is called the "*semicircular*" deviation, which in iron ships arises chiefly from the permanent or sub-permanent magnetism of the hard iron of the ship caused by the process of hammering, and consisting chiefly of an attraction of the north point of the compass to that part of the ship which was south in building; but I propose to confine my observations almost entirely to that part of the deviation which arise from the transient magnetism induced in the soft iron of a ship which is independent of the position of the ship in building. To describe this intelligibly, I must ask leave to introduce you to the "*three soft iron rods*," the apprehension of which gives us such a command over the effect of the iron in a ship. If a thin soft iron rod is held in any position, its south end will attract and its north end will repel the north end of the compass needle. The effect of such a rod is therefore very easily estimated, and even computed, when its inductive capacity is known. Theory then furnishes us with this remarkable result, that if the compass is placed in the midship line of the ship, the effect of all the soft iron in the ship, however irregularly distributed, provided only that it is symmetrically arranged on each side of the midship line, may be represented by three imaginary soft iron rods, the direction of each of which passes through the centre of the compass; one rod called *a* lying fore and aft, another called *e* lying athwartship; the third called *k* being vertical. If the whole rod lies on one side of, or as it may be called "outside" the compass, its effect is to increase the directive force of the earth in the same direction. This is denoted by giving the rod a + sign. If the rod passes through the compass, so as to have one end on each side of the compass, it diminishes the directive force of the earth, and this is denoted by giving the rod a − sign. The effect of these rods in producing a deviation is easily traced out. It is shortly this—

\+ *a* increases the directive force and the quadrantal deviation.
− *a* has the reverse effect, neither + *a* nor − *a* affects the heeling error.
− *e* (and no case of + *e* is known) decreases the directive force, increases the quadrantal deviation, and gives a heeling error to windward.
\+ *k* gives a heeling error to windward.
− *k* " " leeward.
neither + *k* nor − *k* affects the directive force or the quadrantal deviation.

These may be illustrated by the following diagrams and tables:—

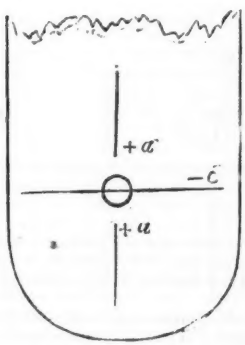


Fig. 1.

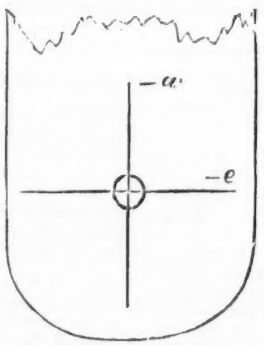


Fig. 2.

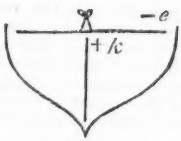


Fig. 1.

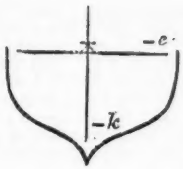


Fig. 2.

Effect of the three soft iron rods.	Quadrantal deviation (+ increases − diminishes)	Directive force (+ increases − diminishes)	Heeling error (+ to windward − to leeward)
+ *a*	+	+	no effect
− *a*	−	−	no effect
− *e*	+	−	+
+ *k*	no effect	no effect	+
− *k*	no effect	no effect	−

It may easily be shown that if a rod whose centre is coincident with the centre of the compass is moved in a direction at right angles to itself, as for instance, if a transverse rod is moved forward or aft, the effect it produces is exactly the same in kind as before, though diminished in amount. Thus, iron beam in a ship extending from side to side will simply produce a − *e*.

If these simpler rules are apprehended, we are in a position to estimate the effects of almost any arrangement of soft iron.

1. The effect of the hull and the iron decks of a ship on the compass, placed at a certain height above the deck, will give—

− *a*, − *e*, + *k*,

e being numerically greater than *a*.

The result is—

1. To diminish the directive force of the needle.
2. To give a quadrantal deviation.
3. To give a heeling error to windward.

2. The effect of an iron beam is, as we have said, to give − *e*, and thus—

1. To diminish the directive force.
2. To give a quadrantal deviation.
3. To give a heeling error to windward.

3. An iron bulkhead, reaching from side to side, under or nearly under the compass, particularly of the nature of an armour bulkhead, has a very formidable effect in giving a large − *e* and a + *k*, thus diminishing the directive force and giving a large quadrantal deviation, and a large heeling error.

4. Gun turrets or iron masts or funnels, and the boilers and engines of a vessel, if entirely before or abaft the compass, will give + *a* and − *e*, and so give a large quadrantal deviation, but will rather tend to increase the directive force.

5. If the boilers are immediately below the compass they will give − *a* and − *e* and + *k*, and, therefore, diminish the directive force, and give a large heeling error, but will not give much quadrantal deviation.

6. The armour-plating of a ship, if continued from end to end, as in the "Royal

Oak" and "Minotaur," is not so prejudicial as might be supposed as first sight, because it will give a large $-a$, a small $-e$, and a $-k$, and, therefore, will rather diminish the quadrantal error and the heeling error, and its principal prejudicial effect will be in diminishing the directive force. If, however, as in the "Warrior" and "Black Prince," the armour-plating is not continued from end to end, but stops short near the position of the standard compass, and there is there a transverse armour bulkhead, then there is a small $-a$, a very large $-e$, and a $+k$, and there is a very large quadrantal deviation and heeling error, and a small directive force.

7. Any iron placed immediately below the compass, and within an angle of 54° 45′ of the vertical passing through it, is very prejudicial by giving $-a$, $-e$, and $+k$, and diminishing the directive force and giving a large heeling error.

In such cases as we have been considering, the great source of evil is a large $-e$, and it is of great importance to diminish this as much as possible. This may be accomplished to some extent by having the part of the deck immediately under the compass and for an angle of about 35° 15′ on each side of the vertical, constructed of wood, the iron beams being, if possible, cut, and their ends inserted in a fore and aft beam, and if this wooden space can be made a continuation of a line of hatchways, $-e$ may be very considerably diminished.

Another point of great importance is to avoid as much as possible placing the compass near the ends of long vertical or of horizontal masses of iron, as the spindle of a capstan, or of a steering wheel, iron masts or funnels, the sternpost, or rudder head. If, however, we must bring the compass near the ends of such masses it may sometimes be possible by a judicious selection of the place to use them as correctors.

Leaving this part of the subject I will advert to one point on which a good deal of obscurity has been supposed to rest, and as to which mistakes are not unfrequently made, viz., the comparative effects of solid and hollow masses of iron. It has sometimes been supposed that in the case of a hollow shot or tank, the magnetism exists entirely at the surface, and that the effect is the same as if it were solid. This is not the case, but theory shows, and it is completely borne out by observation, that the effect of hollow masses of iron increases very rapidly with the increase of the thickness of the iron, and whenever the thickness is more than a very small proportion of the diameter of the body, the effect of the body is sensibly the same as if it were solid.

Mr. Barlow found that the effect of a shell $\frac{1}{10}$th of an inch thick, and 10 inches in diameter, was two-thirds that of a solid sheet of the same size. This exactly agrees with theory. In the case of iron tanks, to which this result may be compared, we get the result that a tank 4 feet diameter, and one-eighth of an inch thick, would have about half the effect on the compass of a solid mass of iron of the same dimensions.

I trust these observations will assist you in some degree in understanding in what manner the theoretical investigations to which I have referred may be put to a practical use in the correction of the deviation of the compass.

LECTURE.

Friday, April 28th, 1865.

GENERAL THE RIGHT HON. LORD HOTHAM, President, in the Chair.

A CLASSIFICATION OF THE CAUSES OF WAR.

By Colonel R. A. S. ADAIR, Aide-de-Camp to the Queen.

MY LORD HOTHAM, LADIES, AND GENTLEMEN: When I accepted the honourable task for which I was selected by the Council of this Institution, I could not but feel that it was one involving no ordinary difficulties, inasmuch as it contains, in its full elaboration, the history of the human race, in its periods of weakness and strength, of triumph and of defeat, of the exercise of the noblest intellectual and physical qualities of man, and, alas! also, of those qualities which cast a disgrace upon human nature. I felt that it was difficult to avoid, on the one hand, descending into too minute details; and, on the other, producing so vague an impression that any attempt to explain the views which I submit to you this day might fall, from their very largeness, dead upon your ear. But remembering that in the material and in the intellectual world there is no violent dissociation of causes from effects—that where there seems to be abruptness, there is still, so to speak, no solution of continuity; it did occur to me that I possibly might find some key by which I might be able, perhaps, to discover, and to make manifest, a not altogether insecure foundation for the hypothesis which I venture to frame in connection with the great facts that stand recorded through all history.

From these remarks will be excluded all those stories of human prowess, intelligence, and valour which are recorded in the early history of all nations. Mythological histories of the wars of the Hindoos, such as pleased the wild tribes of Central Asia, as depicted in their early literature; the Sagas which delighted our forefathers in the northern parts of Europe; the legends of monarchical and republican Rome, and the wondrous tales, which have exercised the genius of the

greatest poets and dramatists of Greece; all these I purpose to set aside, and to take my stand on the facts of recorded history.

In treating a subject wherein the material is so much blended with the intellectual, it may not be amiss to premise the appropriate division in considering the question at large. The world over which the wars that I shall have to name to you, however briefly, have been waged, is distributed into three principal masses. The first, Central and Eastern Asia; the second, Western Asia, Europe, and Africa; and the third, the New World. With regard to the first and last of these three, it is not proposed to deal very closely with the incidents which we have to review; in the first, because the attribute of permanence has, to a great extent, been denied to the operations of war in those regions; and in the last, because from the comparative infrequency of struggle, there is but little for the historian to record.

Commencing then from the central division, and in reliance on this principle, that there is no absolute solution of continuity between successive eras, however difficult it may be to determine distinctly the period at which one era ends and another commences, the Western Asiatic, the African, and the European wars may be classified into six great divisions. These divisions will receive their name and attributes from the prominent national feature which seems to fix the character of the era. The first will be called the Assyrian; the second, the Greek, or Macedonian; the third, the Roman; the fourth, the Arab or Oriental; the fifth, the early European period; and the sixth and last, the late European period. The first period terminates, with the destruction of the great empires of the east by the entry of Alexander into Babylon; the second at the occupation of Corinth by the troops of the Roman republic; the third, when Ricimer, the barbarian, virtually abrogated the western Roman empire by his sixteen years' occupancy of Rome, although the eastern empire fell at a later interval; the fourth is terminated by the withdrawal of the Arabs from Spain; the fifth commences with the period immediately subsequent, and has its principal development in Germany, and continues to the Peace of Paris; the sixth ends with the Treaty of Villa Franca.

It has been said that the history of the causes of war is the history of the human race; and, in accordance with the progress of the human race, it would seem that these causes spring from material and purely physical incidents, and that as mankind advances in civilization and in knowledge, causes more and more artificial are introduced, until, finally, we are brought to that point of time at which we, from our personal judgment, can form an estimate, to a great extent, of what the causes of war may be.

First, then, of the Assyrian period. In speaking of the Assyrian period, those mighty monarchies are recalled which rose, so far as accurate history is concerned, like an exhalation from the deep. To this era, the Assyrian, the Babylonian, the Mede, the Persian, the Egyptian, the Parthian, and the Scythian have given their peculiar characteristics, and demand special attention in investigating the primitive causes of war. These, it may be apprehended, have arisen from the territorial necessities of the state, and here it may be re-

marked that, although we possess in Sacred Writ the coincident and corresponding narrative of some of the events through which these empires ploughed their way, when they were employed as mighty instruments for a mighty purpose, it is not intended to bring that portion of the question under your consideration. In those records are to be found the facts predicted of those empires; and we learn, also, in part, from profane history by what agents the results were carried out. The Assyrian empire, remounting far into the mists of time, recalls to our recollection the memories of those old chiefs—Ninus, and the great soldier-queen Semiramis, and that long range of conquerors whose images look down from the friezes of the lately discovered monuments of Nineveh. Its name is connected with the incidental and consequent wars, and the brilliant fortunes and fate of Egypt, a kingdom in no way inferior to its great northern rivals; for if the tide of war flowed southward across the Syrian desert, it poured also northward again, impelled by the victorious arms of the Egyptian kings. The territorial necessity, therefore, I would insist, was the primitive cause of the wars into which these empires were plunged.

As time wore on, and the later civilization of the regions to the westward arose among the islands and continents of the Mediterranean, a new element was introduced as a necessity resulting from the territorial position of the dominant kingdom or empire of the age. For instance, the pretensions of the Persian King, then the monarch of the greater part of the civilized world, led to the wars that brought the Greeks into Asia, and which ended in the destruction of the Oriental empires. Nor was it in these instances alone that the Greek wars were waged. Wherever an intelligent community was settled, it appeared almost certain that, from the emulative genius of that remarkable people, some war was soon to be waged with a neighbouring State, some power to be grasped, some domination to be raised above the dead level of the Greek people. Here is developed, for the first time, a doctrine which has mainly actuated and guided the policy of Europe in later ages, suspended for a season by the overwhelming power of the Roman empire, but for the first time exercising among the Greek States a beneficial and fortunate influence upon their political career. It was to maintain "the balance of power" that the Peloponesian war desolated Greece for so many years. It was to maintain the balance of power that leagues were formed in succession against Athens, Sparta, and Thebes, and that the glorious contests of the Greek colonies were carried on with an intelligence and an enterprize which no wars in the later history of the world can excel. It was to maintain the balance of power remorselessly threatened by the Persian King, that the type and most eminent of Greek soldiers, Alexander, crossed into Asia and utterly destroyed the Persian empire and the rule of the vast powers which had been consolidated under the great Persian King. But not alone was that empire destroyed, but in the very process of ruin there arose from it kingdoms governed by his Lieutenants. Bright and clear the Greek rule and intellect pervaded the sluggish kingdoms

and satrapies that had been formed in the Persian empire. Nor was the result of the conquests limited to Asia, but, driving its power deep into the heart of Africa, a Greek Egyptian kingdom exercised a most fortunate influence over the eastern portion of that continent.

So for a time the Greek wars waxed and waned, unnoticed by the new power that was rising to the westward. A poor and barbarous people, collected, as it would seem, from the refugees of other districts of Italy, found on the Seven Hills of Rome a cradle from which their glory was to spread until it overshadowed the world. With the history of the Roman people begins the history of national wars. Here again a new element assumes a place among the causes of wars. When the Romans struggled and overcame, in the first of their conflicts, their northern Etruscan neighbours, and when they strove for their existence with the hardy dwellers on the Samnite Hills; when, after many battles, they finally conceded the right of citizenship to those whom they could overpower only upon such terms, then the entire Roman nation was welded by national wars into one mighty and magnificent aggregation of national power, founded and maintained within the limits of the Italian peninsula. But hardly was it consolidated, the gristle of the nation had hardly become the bone that was destined to carry a great work through the world, before another and new feature of war showed itself, pressing hard on the young energies of the republic. The Gauls triumphant in the Capitol, were the precursors of the Teutons and the Cimbri in northern Italy, of the dwellers on the southern slopes of the Alps, and of those who, recruiting their energies from beyond their snowy fortresses, formed the advanced guard of the tide of nations, whom an irresistible impulse in the old, as in the new world, drove headlong on the territories that lay beneath their gaze, as soon as the want of the means of subsistence pressed on them. The wars of emigration had commenced. In later years the Roman empire was destined to find its conquerors in the emigration of those northern swarms, as the Eastern empire also found a principal cause of destruction in the emigration of another portion of the barbarian tribes of Central Asia. There was also a stern contest with the Greek race. The great Punic wars, arising in immediate expression and historical incidents from a trifling cause, were, it cannot be doubted, the representation of an old political grudge, and became a struggle for power which could only be terminated in subjection, utter and complete, of one of the combatants. The Punic wars, however, introduced no new element for classification, but show with what intense energy and animosity a struggle between rival States may be conducted when the prize is the empire of the world.

We have, then, at this period of our review, noticed the territorial causes of war, the political causes of war, and the dynastic causes of war, to a slighter extent prevailing among the successors of Alexander, the wars of emigration which pressed upon the Roman republic, and the national wars which consolidated their powers. But in its progress to empire this great State was not destined to escape from a

war which plagues and confounds the policy of nations. The Romans had suffered from wars of faction, which were simply designed to substitute one form of domestic government for another, that is, the plebeian for the aristocratic; but there waited upon their career a greater plague than any they had known, in the great civil wars by which the whole constitution of the Roman empire was changed, in the wars of Pompey and of Cæsar which supply the clearest and best marked type of the tendency of civil war unaccompanied by religious animosities and considerations. For as up to this period the element of religious warfare had not entered into the disturbing causes of European, that is to say of Roman tranquillity, it was reserved to a later age to show with how sharp an edge the sword of the soldier is fitted for such contests.

It has been said that no religious wars had, as yet, disturbed the tranquillity of the European, that is of the Roman, world. But there is one war which cannot be passed over, remarkable in its incidents—still more remarkable from the instruments with which it was waged; in the enduring type into which it welded a people, and in the national character which was thereby aroused to survive, even to this day, defeat, dispersion, and disgrace.

While the Egyptian kingdom was yet in its pristine strength; while the exploits of its leaders were depicted on the walls of the pyramids in the long procession of conquered nations, from east, from west, from the interior of Africa, and from the hills of Asia, a shepherd population, caring but to maintain themselves in the exercise of their civil life, was gradually increasing in a significant cluster in the lower parts of the delta of the Nile. Their history is recorded in words which are burnt into our memories by the intense beauty of the language, which tells how this shepherd people passing across the Red Sea, and purified by the long sojourn in the desert, emerged on the hills that look on the eastern shores of the Mediterranean—a race of warriors such as the world has never seen excelled. They were no inconsiderable adversaries whom the Hebrew people met when they passed the Jordan; the Anakim, the men whose cities reached up to heaven; the tribes of Canaan—the chariots of these many nations, all were met, all were conquered by these men, instruments in the hands of the Great Power who sent them forth. That was the most remarkable of the great wars in which a people has been selected as instruments. Yet the instances are rare of great wars of an unmixed religious type. Religious enthusiasm precipitated, as has been well said, Europe on Asia in the great Crusades, and led Saint Louis into Africa. The crusade against the Albigenses, and the war of Bohemia under Zisca, were purely of a religious character.

To resume.—For a time the Roman empire remained in its tranquillity. It had absorbed and consolidated all that was then known of the civilized world.

Within lines drawn from the Caspian to the southern headlands of the Red Sea, and from the outfall of the Danube into the Euxine to the Forth, west and south of these limits, even to the remote pillars of Hercules, civilized society reposed under the majesty of the sceptre of

Rome. But the elements of a new struggle and a great confusion of nations and tribes were preparing in dissimilar and widely separated regions. The fanatics—and I use the word as expressing the intense feeling which urges the religious conqueror—the fanatics of a small district in Arabia founded a power, trifling in its origin, but which with a swell like that of many waters, poured forth its hosts athwart North-eastern and Central Asia, over the Indian seas to the islands which are scattered so lavishly through that fair expanse of ocean; downward through the African continent, until they met the Caffre, or "unbelieving" savages of the southern plains; westward along the shores of the Mediterranean, northwards into Syria, and thence menacing the Greek empire, the Arab power manifested itself with a suddenness and energy which the torpid world was not prepared to encounter. I do not pause to direct your attention to the establishment of the Caliphat of Bagdad or of Egypt, or of the powers that were scattered along the Mediterranean. Yet mark, how by victory after victory, effort after effort, this tide of war poured on until those whom it bore aloft, paused on the shores of Africa, prepared within brief space to rend from its possessors the kingdom of the Visigoths. And in the north, another race was preparing for conquest. Tribes nurtured amongst their solitudes and fastnesses in hatred of the Roman name, and in contempt for the Roman provincial with whom the Romans occupied their frontier States, were already mustered in force, had swept backwards and forwards through the northern and north-western parts of Europe, till they were arrayed face to face with the Arab invasion arising in the south. It is exceedingly difficult to convey an accurate and clear idea of the manner in which these conflicting tides surged, and ebbed and flowed, till each corner of Europe became a theatre of strife, and a prize of conquest, in the great quarrel of nations. It is exceedingly difficult, it is not possible, in such brief space to show in coincident and contemporaneous columns how the invasion of the German nations on the Roman empire along the northern frontiers coincided precisely and identically with the action of the other and great power of the Arabs on the Byzantine confine along the southern and eastern in accurate and precise detail; but whereas the Roman empire had fallen in Western Europe before the successive invasion of the races which became masters of the Italian peninsula, and as the provincials had found the Roman power had finally passed away, although vindicated for a time by the great victory of Chalons, so the two great migratory masses of mankind, sweeping around the northern and southern borders of the civilised world, were arrayed for that final and decisive conflict in the battle of Tours, of which the results would leave Western Europe Mahommedan, or Christian. From that period the Arab and Saracenic invasions retired. The ebb had set in. The perseverance of the Visigoths, who never despaired of their country, was rewarded at the siege of Granada by the expulsion of the Moors. The position of Mahommedanism in Western Europe, as in Western Africa, was fixed as it has remained to this day, with the exception of the interposed kingdom of Algeria, on the northern shores of Africa, and the par-

tial resumption of Greece and some islands into Christendom. Such was the mighty result of the wars of emigration.

For the eastern empire a later doom was reserved. Threatened from the south by another wave of this Oriental invasion of the Saracens, from the eastward by the irruption of the Turkish power, properly so called, of the Kurdish shepherds, and the Seljukian tribe, already hemmed in within limits narrowed of old, on the north-eastern frontier, by the continuous inroads of Goth, Hun, Bulgarian, and the myriad tribes which were impelled down the western slopes of the Ural by the restless impulses of emigration, the Byzantine empire at last, and within the times of modern European diplomatic history, fell, and Mahommedanism and Christendom were then ranged face to face along a well-marked line of frontier, with the exception of the territories that form Algeria and Greece. This collocation of powers would naturally lead to a state of political distribution, in which a central state might be successful in occupying a position dangerous to the liberties of the civilized world, and so it proved. That principle which had been suppressed for many generations, which, as has been noticed, flourished in the intellectual and civilized policy of the Greek republics, again emerged in vindication of the balance of power. The wars of Charles V., of Philip II., and Louis XIV., all belonged, though at different eras, to the first period of European history; they were wars carried on to maintain the rights of the smaller States on the one hand, and to restrain the greater powers on the other, from extending empire wider than was consistent with the repose of the European commonwealth. In close connection with wars of this character, wars of succession, wars of aggression, and wars that may be properly called dynastic, another class of struggles arose. Nations submitted to over-shadowing rule of alien monarchs unwillingly, and vindicated their liberties as occasion served. It was a war of liberation which the Seven Provinces waged against Spain, although it partook of the nature of religious strife. It was a war of liberation, when Portugal freed herself, under the Braganza, from the rule of Spain; it was a war against utter subjection that this country waged with the Spanish monarchy, when the Armada was dispersed and shattered; and in the long struggles consequent upon attempts to extend dynastic power, the element of religious strifes pervades the wars that desolated Europe. The Thirty Years' War was partly of a dynastic character, but it was especially of a religious type.

But apart from these, and the civil wars of the League and the Fronde in France, and the great civil war in England, in the former and latter of which religion was again invoked and desecrated, the new condition of European society seemed to have settled down into a state of policy in which it was probable that no novel causes of war would probably arise. The Seven Years' War shares the characteristics of the wars that immediately preceded it, which had been waged against Louis XIV., and against the Austrian and Spanish monarchies, except that it was personal rather than dynastic, and with the Peace of Paris the era closed. A novel motive power was about to be evolved in the dynamics of war, a power whose influence has not waned to this

day—which will probably sway national policy until war shall be no more. The revolt of the Thirteen Colonies inaugurated this new age, and introduced to the European mind an unforeseen provocation to battle. Then, for the first time, was a struggle developed, directly and indirectly, throughout the European continent for the extension and maintenance of the revolutionary idea. And by the revolutionary idea is meant the governing formula of a revolution, such as adapts old forms to new wants, but by a process in which, nevertheless, the old forms must accept destruction. France was the first to lead in this career; from 1789 to 1815 every battle was fought, every capital was occupied, taken or retaken, for the vindication of either the stationary or the aggressive principle of policy in dealing with revolutionary ideas, of inevitable and excessive change. With the battle of Waterloo, the exhaustion of Europe gave breathing time for a longer period than had been previously known for centuries. The wars of liberation of Servia, of the Central and South American colonies of Spain, and that of Greece, occupied the interval between 1815 and 1830; until in 1830 the three days of Paris again set prominently forward the ideas of '89, and so from 1830 to the Peace of Villa Franca, that has been the principle upon which European wars have been conducted and fought. The Belgian war of liberation succeeded instantaneously to the change of government in France; nation after nation felt the pulsation vibrate through it; but not in all cases did they bring the harvest from the soil.

But in 1848, the next epoch or stand-point in this era, what was the aspect of political Europe? Thrones trembling in every direction, peoples arising in wild disarray, and the new doctrine of nationalities prominently evoked. Hitherto a war of nationalities, as distinguished from a national war, has not been successfully fought; whether such a war be reserved for the future, it is not for us to say; but there are strong indications of the tendency of nations to group themselves according to language, customs, and manners, with relations hostile or friendly. And so the last war, great in its inception, vast in design, brief in continuance, was commenced, as the chief author told Europe, for an idea. Upon the components of this war, as probably upon all wars of these later days, a mixed character is and will be imposed. The Lombard people fought against the Austrian strangers; the Piedmontese armies fought against the Austrian on grounds of political weight; the Neapolitan and the soldiers of Central Italy fought against the Bourbon family; and under the auspices of liberty, springing from this coalition of causes, Italy has become Italian, and been formed, with but one speck at the core, into a homogeneous mass, mainly under the impulse of the ideas which belong to the revolutionary period. A later war than that which terminated with the Peace of Villa Franca has, it is true, been waged.

The various and complex causes of war have been passed in review —territorial, political, religious, dynastic, wars of liberation, civil wars, wars of revolutionary ideas, national wars, and those which result, as it were, from the physical necessity by which nations are compelled to precipitate themselves into districts of the world which invite by

their fertility or by unoccupied space. The worst of all wars, in my judgment, is a war waged for a purpose that is not avowed. If we mark a war undertaken and justified on the assurance that it is intended for the benefit of those who shall be rescued by the invading power, from harsh, bitter, alien rule; if this be accompanied by a declaration of an independent and self-denying policy as to the opportunities that such a war may present, in its progress, for aggrandisement; if it appear also that there is a purpose to conduct operations in the civilized and humane spirit that befits the age, then, whatever be the opinion as to the just policy of those who originate the war, judgment may fairly be suspended in the hope that good may arise from the appeal to the terrible arbitrament of combat. But if time shews that such words are dissipated into thin air so soon as the object is attained; if the people, on whose behalf these pretensions have been alleged, unrestored to the exercise of their liberties, are compelled to cluster round the chariot-wheels of the conqueror; if, especially, the war has been carried on with a harsh and unnecessary exercise of overpowering military force, then we are justified in believing that the causes of that war are such as can never lead to a prosperous, or a righteous, termination. We are bound to rebuke the statesmen who have originated, and to withhold our sympathy from a people who have lent themselves to such a strife, while we regret the destination of the skill and valour of the soldiers employed on such a task.

In all ages is recorded a Nemesis for the nations. It has been well said that war generally leaves a people poorer, almost always less virtuous, than at the commencement. That is the Nemesis prepared for those who wage an unjust war. The great Napoleon forgot the dictates of eternal justice when he weighed down Prussia with her chains; but the Prussian Hussars bivouacked, at length, in the Champ de Mars. There is a lesson which should never be forgotten.

I have omitted, hitherto, to refer to the periods of uncertain and ill-defined strife that extended over the Central and Eastern Regions of Asia, chiefly, because no very large or sufficing hypothesis can be framed from the occurrences related, and in most instances, with a very imperfect attention to historical precision. Bajazet, Tamerlane, Ghenghis Khan, Mahomed of Ghuznee, Nadir Shah, and a long line of Tartar, Mongolian, and Chinese conquerors; the Malay Sultans, the Chiefs of the Indian Archipelago, those who carried on almost unknown and unrecognised wars in the great Peninsula of India, or the tribes of the Persian Gulf, the dwellers in the hilly regions of Beloochistan, and thence to the Russian frontier, have swept across the earth, with devastations but too evident, yet leaving no impression but that of a blind purposeless fury. There is, however, a never-ending series of wars waged by our own Empire in the East. But that branch of the vast history of war is too intricate and complicated to be touched upon at present. But that long and chequered story should especially lead the statesman to consider with severest effort the duty of civilized and powerful man, when he is brought by force of circumstances into collision with races less powerful, whether it be from the weakness that results from exhausted civilisation, as in the Indian

peninsula, or from the undeveloped resources to which civilization has not given strength, as among the tribes of the Caffre territory and New Zealand colony.

Another region of the earth yet remains to be noticed. In regard to the ancient races of the western world, it would seem that the Aztec, or Mexican, and the Peruvian nations were alone entitled to be considered a powerful and enduring people. Doubtless there were other races of whom the only records are found sculptured, but uninterpreted, in the depths of their primeval forests. It was not to be doubted, that as soon as European civilisation had established its colonies, its religion, and its customs, in both portions of the western hemisphere, strife would prevail. The French and British powers carried on, scarcely a century since, wars with equal violence in the plains of Northern America, as in those of Germany.

Spain and Portugal long maintained under their unbroken rule the southern portion of the western world; and it was not till the wars of liberation, consequent on the European convulsions of the great French War, wrested her colonies from Spain, that notice need be specially taken of the wars of South America. Lastly, although it is not the place or time to declare and adopt a decisive opinion on the causes of the terrible struggle that has lately devastated the northern continent of America (the historian will have pains enough to arrive at a just conclusion), yet I may take an opportunity of making one remark upon that war before I conclude. For the moment, I will ask your attention to the judicial literature of war, as shown in the writings of those who have attempted to impress legalised form and consistency on national relations. Vattel, Grotius, Puffendorf, Wheaton, and others, have written on these subjects, and the Caliph Othman II. himself has left a code of war on the treatment of prisoners, and on the relations which should prevail between infidel and Mussulman, during a period of war and after the war has ceased, of a very remarkable and instructive character. Vattel, amongst others, has endeavoured to define the justifiable causes of war in two sentences, which, comprise, as it seems, his complete opinion on the subject:—

"Si une nation prend les armes lorsqu'elle n'a reçu aucune injure, "et qu'elle n'en est point menacée, elle fait une guerre injuste.

"Celui-là seul a droit de faire la guerre, à qui on a fait, ou à qui on "se prepare à faire injure."—Vattel. Droit des Gens.—Lib. iii, ciii, § 27.

The injury that has been done, is easy to be remedied; with regard to the injury that may be threatened or apprehended, therein lies the chiefest difficulty of statesmen. He proceeds:—

"Nous deduirons encore du même principe le but, ou la fin legitime "de toute guerre, qui est de venger, ou de prévenir l'injure."—*Ibid.* § 28.

How far it may be in accordance with the improved civilization and humanity of our day, to avenge as well as to prevent injury, is again another problem for the equitable sagacity of statesmen. I remark here a most striking expression of opinion from a high legal authority, Judge Haggarty of the Canadian Bench, in the case of Burley, arising

from the war in the United States of America. Burley was claimed by the Federal States' Government from the Canadian authorities for certain acts of piracy alleged to have been committed 18th September, 1863, on board a passenger boat on Lake Erie, belonging to a citizen of the United States, under colour of an alleged commission from the Confederate States.

Justice Haggarty says, "No writer of repute seems to distinguish "with a firm hand the point where war ends and murder begins; "between lawful prize and petty larceny.

"Many jurists tell us how they think war should be waged in the "light of improved civilization, but seem to shrink from the definition "of settled principles governing its conduct."

Must it not then be especially the duty of the statesman, and of those who influence the councils of nations, to pause before resort be had to so terrible an arbitrament, to so dread a tribunal.

Some remarks may be admitted in respect of the wide-spreading struggle which is for the time suspended in North America, and thus we are brought to think of the recent terrible event which has excited, as has been well said, the horror of the civilized world, and thus also of another death-bed, equally significant in its moral. The Great Napoleon, whose name for 25 years had sent fear, or encouragement, or provocation to battle, according to the temper of the listener, throughout Europe, having survived the last of his field, remained to die peacefully—he, eminently the man of strife—in a lonely island of the Southern Atlantic. There is a passage of remarkable significance in the lyrics of one of the poets, who lend themselves with true French national feeling to develop the character of their hero who had done so much for France. He says, in eloquent illustration:

"Et tu mourus cependant de la mort du vulgaire,
"Ainsi qu'un moissoneur va chercher son salaire,
"Et dort sur sa faucille avant d'être payé:
"De ton glaive sanglant tu t'armas en silence,
"Et tu fus demander justice, ou récompense,
"Au Dieu qui t'avait envoyé."

"And yet thou died'st the peasant's death, as reaper comes at eve
"For pay, and dozes hook in hand ere he his wage receive;
"With gory sword thou silent went'st thy way for doom to ask,
"Or meed, from God who sent thee forth, and meted thee thy task."

That man of war died peaceably, surrounded by the friends of his fallen fortunes. There was another figure prominent as his in a war whose slain have outnumbered those of any European conflict, who died by the violent death that rarely strikes down the political chief of a people. And when the feverish strife shall have passed away, let us desire that all that blood shed on the great Northern American continent has not been poured out to barren purpose; that those homes which have been made desolate, have not been made so desolate but that there even hope may spring again with the revived prosperity of the great Republic. But whatever the result, history will regret, that at the very moment when there was but one man

round whom had gathered public confidence sufficient to enable him to heal the strife, when that man was standing on the threshold of a noble enterprise of pacification, he was struck down by the hand of an assassin.

And so the wars of this world, the actors and the sufferers in them, all alike pass away. There is almost a prophecy, from him who alone in the present day unites in the old sense prophet and poet, applicable to our improved civilization.

" And yet, if Nature's evil star
" Leads man, in manhood as in youth,
" To follow flying steps of truth
" Across the brazen bridge of war ;
" If new and old, disastrous feud,
" Must ever shock like armed foes ;
" And it be true till time shall close,
" That principles are rained in blood ;
" Not yet the wise of heart would cease
" To hold his way through fear or guilt,
" But, with his hand against the hilt,
" Would pace the troubled land like Peace.
" Nor though the dogs of Faction bay,
" Forsake his kind in deed or word ;
" Certain, if knowledge gives the sword,
" That knowledge takes the sword away."

LECTURE.

Friday, May 12th, 1865.

REAR-ADMIRAL SIR F. E. NICOLSON, Bart., in the Chair.

VENTILATION OF IRON-CLAD SHIPS OF WAR.

By Dr. EDMONDS, Staff Surgeon, R.N.

BEFORE entering upon the special consideration of the ventilation of ships, I must request your attention to some preliminary remarks upon the subject of ventilation in general, as it is necessary in order rightly to appreciate the measures which I shall bring under your notice, as effective in accomplishing so important an object, to be acquainted with the principles which have suggested them; and as different opinions prevail on many important points connected with ventilation (which, according as we are influenced by them, must materially modify our arrangements), so if I am able to convince you of the correctness of my views, as to the changes which take place in the air from respiration and other vitiating causes, I shall scarcely fail to satisfy you as to the effectiveness of the means I recommend for the ventilation of iron-clad ships. Ventilation means circulation of air; and this circulation of air, vitally necessary for the maintenance of organic life, is admirably provided for by nature through the influence of the law of gravitation. This same Divine law—which keeps the earth and the other planets in their appointed course round the sun, which causes currents and tides in the ocean, winds in the atmosphere, and rains upon the earth—is also the mainspring which sets in motion that circulation of air which is so essential to the nutrition and existence of all organic life. I need not remind a scientific audience how gravitation accomplishes these mighty objects, further than to show its bearing on scientific ventilation. To enable this beneficent law to act, the Divine Author of nature has ordained another by which all air which has been respired, or has been in contact with animal bodies, becomes specifically lighter, though only temporarily so, than the surrounding atmosphere, and, therefore, for a time rises in it; the atmosphere, by its superior gravity, or by gravita-

tion, forcing it upwards until it is diffused and carried beyond its late sphere of action, and thus portions of fresh vital air are continually being presented for consumption. Now this lightness of *used* air is due to two causes—first, in being heated, air expanding $\frac{1}{490}$ for every degree of temperature; and, secondly, in its containing a large portion of aqueous vapour, which is of a lower specific gravity than air.

Now there is another point I beg to call your attention to, although the substitution of carbonic acid for oxygen in expired air does not, owing to the counteracting influences I have mentioned, give it a higher specific gravity than the atmosphere; upon what becomes of this carbonic acid depends in a great measure how we can most effectually ventilate; because it is known to be so heavy, it has been assumed that from its gravity it would settle down and collect, so as to form the lowest stratum of a confined space, such as exists on board ships; and, consequently, as this is the most noxious product of respiration, persons taking this view would direct their ventilating efforts to the part where they suppose this foul air to gravitate; but I venture to affirm that under all ordinary circumstances, no such gravitation of carbonic acid takes place, being mixed, as it leaves the lungs, with aqueous vapour and heated air, these give it, as it were, wings to rise with, until it is diffused into the surrounding atmosphere; but if this air is so confined that it cannot escape upwards, then the same air must be breathed over and over, as it again descends when cooled, until it is overloaded with carbonic acid, and then it *must* gravitate below; thus in the confined decks of ships, frozen up in Arctic seas, where, to keep out cold, minimum apertures are left for the escape or admission of air, such saturation of air with carbonic acid may occur. And this cannot excite our wonder, when we consider that air loses during respiration about 6 per cent. of oxygen, which is replaced by nearly an equal bulk of carbonic acid, and this change would greatly increase its specific gravity were it not for the causes I have mentioned; and if the respired air is in a confined space and allowed to cool, its wings, as it were, provided by nature to enable it to rise and escape upwards, being but temporary, its lightness gone with its reduced temperature, and its watery vapour condensed by the same cause, it must re-descend and be again presented for respiration until the individual is suffocated, unless some means are provided for its escape and for the admission of fresh air.

Many instances are recorded in which carbonic acid has collected in confined spaces in ships. I have lately heard of a case in which, owing to the decomposition of a quantity of materials for making brooms placed in the spirit room of a man-of-war, so much carbonic acid was formed and accumulated, that a man descending soon after the hatch was taken off, was temporarily suffocated; but in a very short time, from the agitation of the air and the access of fresh air mixing with it, all danger ceased. Again, we know that there is a law of nature by which all gases have a tendency to mix uniformly (designated as the law of diffusion of gases), which prevents any such accumulation of carbonic acid under ordinary circumstances. We may fill a tumbler with carbonic acid, as we would with water, from its heaviness, and a taper would be imme-

diately extinguished in it; but, after standing an hour, it would no longer extinguish the taper, therefore how can it collect at the bottom of a ship except under exceptional circumstances?

I hope I have now demonstrated that natural ventilation consists in the escape upwards of foul air, and its being replaced by pure air from *lateral* sources, and where circumstances are favourable for this circulation of air, nature silently and effectively performs this operation for us. In our houses on shore we have plenty of space, and although we persist in having, perhaps, lofty rooms, in which all the cubic space above the door, from having no upper outlet, instead of being beneficial, is positively unfavourable to ventilation: although we try to shut out the fresh air from entering laterally, by what we consider well-made doors and windows; fortunately for us, it can, in spite of our efforts, force its way through their crevices by atmospheric pressure or gravitation, to replace the warmer or more impure air passing up the chimney or through the upper chinks of the doors, and this takes place with a force proportioned to the difference of temperature between the external and internal atmosphere.

I now come to the consideration of the ventilation of ships; and you will readily understand that the mode of ventilating ships and houses must be very different. We have equal or superior facilities, if properly made available, for carrying off foul air; but the main difficulty consists in the supply of fresh air. Again, we have a very large number of people crowded together in a very narrow space, and these usually disposed at night time, of all periods when persons are most susceptible of noxious influences, in the worst position that could be devised. Most of the scientific men who have given their attention to the subject of ventilation prescribe a certain amount of cubic *space* as being necessary for healthy respiration, and their estimates vary from 500 to upwards of 1,000 cubic feet for each person. Now these rules cannot possibly be carried out in ships, where, from our means of ventilation being so limited, a large amount of air space seems more essential, I must, however, beg to differ in opinion with those who maintain that so large a quantity of air space is absolutely necessary for a human being healthfully to subsist in. Even with 500 or 1,000 cubic feet of air space, you cannot dispense with ventilation; with it judiciously arranged, so far as pure air supply is concerned, a man may have a sufficiency for healthy respiration in a very small space. Theoretically, he might live and breathe healthfully in a box no larger than a coffin placed upright, if a gentle stream of air were kept constantly passing through it, entering below at one aperture while it passed out at another above, and with a cold outer atmosphere. Mere apertures above and below of a few square inches each would suffice to keep up sufficient circulation of air to sustain life. If fresh portions of air were constantly presented for respiration, and the respired air was immediately carried off and prevented from mixing with the air for the next respiration, 10 cubic feet per hour only would be required to keep the blood supplied with oxygen, and to carry off the carbonic acid, &c., in expiration, this being the actual quantity, ascertained by careful experiment, passing through the lungs in that time.

The cubic space for each man in our most roomy man-of-war rarely amounts to nearly one-half of the lowest estimate of what is thought necessary on shore; but in fact, owing to the mode of sleeping in hammocks usual in all men of war, not *one-fourth* part of the limited deck space is really available for respiration. The hammocks are slung close beneath the beams, forming—as each man is ordinarily allowed only 14 inches of lateral space—a compact platform, separating the foul air, which soon collects above them, from the comparatively pure air below. Often have I, when serving as surgeon of a line-of-battle ship, in going round the lower deck at night, had my attention called by the commanding officer to the freshness of its atmosphere as experienced by us in walking along *under* the hammocks. It was some time before it occurred to me that there might possibly be a difference in the air space above, and when I put this to the test by raising my head above the hammocks—rather a difficult operation—I only felt surprised that men could exist for any lengthened period in such an atmosphere. That it is very deleterious there can be no doubt, it being fully evidenced by the prevalence of diseases such as would be caused by overcrowding; by physical deterioration; and an appearance of premature old age, which, I believe, sailors exhibit more than any other class, and more than we ought to expect among men in the prime of life, well fed and cared for, and removed for a great portion of their time from those noxious influences to which people of their class when living on shore are subject. Not trusting to sensations alone, I have repeatedly tested the temperature of the space above the hammocks in comparison with that below, and have invariably found it much higher, and the difference greater in proportion to the heat of the weather, the crowded state of the decks, and the means of ventilation employed. I have known the difference in temperature alone to exceed 10 degrees; this was in Malta harbour during a hot, close night, with all hands in their hammocks; and the other impurities of the air must have been in a greater proportion. This air above the hammocks is always so confined by beams across, by hatchway-combings, and by the men in their beds, that it is almost out of circulation, and is only renewed at all by its being slowly forced up the hatchways by the heavier atmosphere from below. Now I have spoken of this great impurity of the air as existing in what is considered an ordinary well ventilated line-of-battle ship; what might we then expect would be the state of things in an iron-clad ship, without lateral ventilation? In the lower deck of the "St. Jean d'Acre," the ship I was surgeon of, we had ports which were opened when in harbour for the admission of air, and these I had made capable of being raised by a simple expedient to three different gradients, according to the temperature. Of course the stagnation of air would be greater in iron-clad ships, and unless the greatest care is taken with their ventilation, they must be necessarily still more prejudicial to the health of their crews.

Now as it is quite impossible, with the means at our command, that we can afford a large amount of cubic air space to men on board ships, owing to their structure, where, moreover, the air is vitiated, not only by the closely-packed crew, but also by the emanations from the ship's damp timbers, and from its confined spaces below, stored

with provisions, cargo, &c., I am not sure that, under all circumstances, it is not rather an advantage that we have so small an area on which to exert our ventilating power, as we can almost immediately remove the vitiated air as it leaves the lungs, and necessarily cause it to be instantly replaced with pure air. I hope to convince you how perfectly this can be accomplished by self-acting means, not limiting each individual to the minimum 10 cubic feet per hour, but by supplying from twenty to forty times that quantity.

In considering ventilation, we must ever bear in mind, particularly in applying it to ships, where we have a large number of people crowded together in a small space, that we have a Scylla and Charybdis to steer between—on the one side cold draft, on the other stagnation. The first causes positive inconvenience, which is nature's warning of danger, to the system; and we know cold drafts may produce acute disease and inflammations, as well as catarrhal affections, to those subjected to them. The other, or stagnation, in a hurtful degree may give no warning to the person sleeping—bathed, as it were,—in his own exhalations, he is warm and comfortable, but its injurious effects, though probably remote, are no less sure. The deprivation of health caused during sleep is only partially neutralized by the healthful nature of the daily life of a sailor—the moderate exercise, usually wholesome diet, and regular life at sea, which should altogether make a sailor's life the most invigorating and favourable to a high standard of health; but it is during sleep that we are most susceptible of all noxious influences, whether from changes of temperature or exposure to malaria, and this unhealthy sleep which sailors are subject to, who sleep in hammocks, more than counterbalances all the other advantages they have.

There is a great difference in the circulation of air, or, in other words, in the degree of natural ventilation between hot, and temperate, or cold climates. While the temperature of the human body remains nearly the same--about 98—that of the atmosphere varies from this degree, or even higher, to the lowest point. With a difference of temperature of 30 or 40 degrees, as in temperate climates, this circulation of air is active enough; a current of air is constantly passing upwards over the surfaces of our bodies as it is warmed by them, and from our lungs, cooling us, perhaps causing the sensation of cold, but giving us a constant supply of fresh air. When the temperature of the air and the temperature of our bodies approaches equality, no such active circulation of air can take place, and it would be entirely suspended were it not for a larger quantity of aqueous vapour being exhaled by the skin as well as the lungs; but it is evident that the means for promoting ventilation in temperate climates are wholly insufficient for a ship serving in the tropics, and as all are liable to be required for such foreign service, they should be equally prepared for it.

Now if we examine the construction of ships—and it is as indispensable to understand this thoroughly in making sanitary arrangements for them as it is for the physician to understand the structure of the human body, whose diseases he seeks to cure—we shall see how the circulation of air takes place at night in a ship's sleeping deck, and the difficulties nature has to contend with in effecting it. Where side ports

exist, so long as these can be opened, they are the inlets for fresh air, while the heated air is continually passing up through the hatchways; and I have shewn that this circulation may take place along a ship's lower deck at night, and yet the space above the hammocks be quite unventilated. But in the lower decks of iron-clad ships there are no ports; in some there were no scuttles; but the Admiralty now, I believe, require them to be provided in all ships where the men mess on the lower deck. But this brings us to the Scylla and Charybdis case. These scuttles, usually about six or eight inches in diameter, number from 24 to 36 in the whole length of the ship. They are open at the level of the hammocks; and as the entire space of the deck is occupied, those must be inconvenienced who sleep near them. There will be necessarily a current of cold night air passing through each. Now it is not in human nature for an individual exposed to its influence to bear such a draught for the general benefit, consequently he silently closes the scuttle, and goes to sleep in comfort; and if other means of ventilation were neglected on account of these being provided, they would be better if non-existing, except to give air and a little, but very insufficient, light by day. For all this, however, these scuttles are an important and valuable addition to ventilation, but screens should be hung up in front of them at night. Their ventilating action must never be reckoned on, as when the ship is at sea they must be closed.

We will now consider the action of the hatchways in promoting ventilation. When there are no lateral inlets for fresh air, these must serve for this purpose, as well as to carry off the foul air, whereas they are only adapted for the latter purpose. To effect this, counter-currents are established, which prevent the air becoming too impure for existence. Heated air flows under the combings and up the sides of the hatchways, while some fresh air finds its way down their centre, and we can, by a central tube carried low down in the deck, greatly assist this operation.

In order to show you how foul air necessarily lodges and stagnates in the spaces overhead, we must first observe that by far the larger portion of air space over the men's hammocks at night is that between the transverse beams, which are about a foot in depth; laterally it is bounded by the ship's sides, except where there are hatchways, and the hatchway combings are about as deep as the cross beams; now suppose we could reverse this deck so that the beams and combings were on the floor, and then if we were to pour water into them, the water would rise to the level of the beams and the combings of the hatchway before it would overflow. As water gravitates downwards, so foul air, while heated and lighter than the lower atmosphere of the deck, is forced and kept upwards by the gravity of the atmosphere, being there equally stagnant as water would be below. As the water would run out in the first case, if apertures were made at the bottom through the deck, so can this heated air only escape freely by apertures placed above.

We see that under ordinary circumstances on board ships, such as are usual at night, owing to the position of the hammocks, in this space above, between them and the deck, which is close over head, and which space it is of vital importance should constantly have its atmosphere re-

newed, the air is almost entirely out of circulation; and here I must request your attention to a peculiarity in the construction of all wooden ships and some iron-cased ships, which leads to a still further vitiation of this important air space. To understand this, we must study the structure of the framework of a ship; and I may observe here that nearly all wooden ships have this same formation, whether cargo ships, passenger ships, or men-of-war. To make this plain to those of my audience who are not conversant with ships, I may state that in building a ship, after the kelson or back-bone is laid down, the ribs, which are separated from each other with spaces between them, are next fixed to it, then the outer planking, and, finally, an inner lining; thus, you will perceive, channels are left between the ribs, extending from the highest part of the ship's side down to the bilges; the use of these channels is partly for drainage, but chiefly for ventilation of the ship's framework, and for this purpose they are left open over the shelf-piece, which is just above the level of the hammocks; they, therefore, form a direct channel communication between the space just above them and that of the sink of the ship, as it were—the bilges—to which all foul matters gravitate, and where the air is always most impure; and these air passages, called timber spaces, are so left open for the purpose of ventilating the ship's timbers, and so preventing dry-rot, although the passive circulation of air which takes place up these openings is scarcely sufficient for the purpose; and, unless a ship is built of well-seasoned timbers, decay too often occurs. For confirmation of this, I need only instance to you the case of the gunboats built during the Russian war; they were built hastily, and of unseasoned timber, containing much of the crude juices of the wood; when this was built up and closed in almost entirely, the dampness could not be exhaled from want of sufficient ventilation, and consequently decay ensued. When they had been laid up for a year or two after the war was over, it was found that the greater portion of them were decayed past repairing, and the country was put to very great expense in almost rebuilding the remainder. The Admiralty, fully sensible of the importance of this circulation through the ship's timbers by means of the timber spaces, require their Officers entrusted with the superintendence of a ship's construction, to sign a book—I believe weekly—testifying that they have examined and ascertained that these openings are clear. I fear, too often, this has been signed from mere routine. I can answer that in one sickly ship, the "St. Jean d'Acre," if such an order was in force at the time she was built, it was not faithfully carried out, and it was to its neglect, I feel convinced, that much of the sickness of her crew was owing. Now, however necessary for the interest of the shipowner it may be, that his ships should be preserved from decay, it is hardly fair that this should be done at the expense of the health of the crew and passengers, as it undoubtedly is; it would be a *parallel case* if we, in our houses on shore, were to ventilate our underground cellars, through which, to make a fair comparison, we must imagine an open drain passing, by means of numbers of air-passages or pipes leading up from it into our bed-rooms to the heads of our beds; and yet a similar arrangement has existed in nearly all ships from time immemorial, and does so still. It has become a very frequent practice lately with shipowners to

pickle their ships, by filling up all these timber spaces with large crystals of salt down to the kelson, and this is especially practised with north country ships, which are peculiarly obnoxious to dry rot; although this is not done with a view to the health and comfort of the crew or passengers, it does, nevertheless, tend to serve this good purpose, and to diminish the foulness of the air; and, I believe, there is no doubt that it has a very preservative effect on the ship's timbers, and is far better than the more general practice of leaving them entirely open into the mess-deck; but they do not entirely obstruct the passage of foul air from below into the decks above, the salt being in lumps allowing a passage through them; in time, too, it melts entirely away unless kept renewed, and so much salt must create dampness. As much as 100 tons are necessary for salting a large ship, thus diminishing by so much her freight-bearing powers, and making it, with the cost of the salt, a very expensive process.

Who, that has been a voyage to India, has not experienced the sickening odour of bilge-water which prevails in a ship whenever, from bad weather or other cause, it has been necesssary to close the ports and cover the hatchways; even ordinarily, with fair ventilation, the smell of bilge is often most offensive, especially in warm climates; and it is always experienced, more or less, by persons first going on board ship. Putting the unpleasantness of these effluvia out of consideration, the deleterious effect on the health of persons sleeping in an atmosphere so tainted must be obvious, not only from analogy, but also from our experience of disease in ships in the tropics, which has, in many instances, been observed to co-exist with a foul state of the bilges, communicated chiefly through these openings to the general ship atmosphere. Independently of these passages conveying foul air from the bilges to the mess-deck, each of these timber spaces or air-channels has an extensive area of internal surface, always in a more or less damp state, often decaying, or containing decaying débris, deposited in them by accident or carelessness; this alone, especially when acted on by a high temperature, is a sufficient source of malaria; and if it does not, under these circumstances, actually generate those fatal fevers, which so often commit fearful ravages in our men-of-war and merchant ships serving in the tropics, there can be no question that such an atmosphere of *ship malaria* serves as a hot-bed in which their germs once introduced, spread with fatal energy.

I have from careful inquiries and observations satisfied myself that there is a far more intimate connection than is generally believed between these local malarious emanations and the ravages of fever in most of the ships which have been notoriously sickly in the tropics; I may instance the "Highflyer," "Firebrand," "Malacca," "Dauntless," "Icarus," and "Eclair;" and this is the reason, I believe, why some ships are continuously sickly, clearly from endemic causes of disease existing within the ship, acting with more or less intensity, according as the ship is located in a tropical or a temperate climate; thus the "Firebrand," when in the West Indies, suffered from a most malignant form of fever, which carried off, during the short time she remained on that station, 53 men out of a crew of 130, and she was then ordered home. It

was assumed that the disease was a climatic one, and although her bilges were notoriously foul, emitting malarious emanations, especially remarked whenever the ship rolled, yet this being nothing unusual in a man-of-war—after her return to England, having been cleared out in a dockyard, so far as it was possible to do so without taking her to pieces —she was again dispatched, and this time to the Mediterranean. The same endemic causes of disease continued to exist in the ship, but their influence was for a time manifested only by an inferior standard of health among the men, and a rather high sick list, the heat of the tropics and perhaps the germs of specific fevers being wanting to develop its full force; but at length the ship went to an unhealthy part of the station—the Coast of Syria, and there the old warning bilge effluvia were again prominent. Fever simultaneously broke out, and had the ship been exposed to the tropical heat of the West Indies, the same fatal results would have been probably experienced, but as it was, though the cases of fever were very numerous, its type was comparatively mild. The "Eclair," alias "Fair Rosamond," furnished a parallel case. When fever broke out among her crew while serving in the tropics, the mortality was frightful; afterwards her name was changed, to obliterate the recollection of it, and she was sent to a temperate climate. Her crew continued to suffer from fever, but in a more chronic and less virulent form. I believe she was subsequently found to be much decayed. The "Highflyer" was found to be so extensively decayed after her sickly commission, that thousands of pounds were expended in replacing rotten timbers alone before she could be again put in commission. During nearly the whole commission of the "St. Jean d'Acre"—one of our noblest two-deckers—in the Mediterranean, her crew were, throughout nearly the whole period, afflicted with a cachectic disease, clearly of an endemic nature, attended in the great majority of cases with nearly all the incipient symptoms of consumption, with a tendency to pulmonary congestions and acute inflammation. This disease once established, could not be cured on board. Most of the cases were sent to Malta Hospital, and were there invalided as being consumptive. Altogether during one year alone, 150 of her crew, out of 830, were invalided or sent to hospital—I think about 260 during the commission. Now the causes I have already mentioned existed in the "St. Jean d'Acre;" her bilges required constant cleaning to prevent their becoming too offensive for endurance, and I clearly traced the connection between this malarious effluvia—its effects aggravated by the ordinary overcrowding of a man-of-war—and the cachectic disease, indicating the existence of a blood poison, which prevailed and was endemic in the ship.

Now perhaps I ought to explain here the reasons which induced me to connect the sickly state of the ship with *endemic* causes. In the first place, in more than one of the accessible parts of the ship, a whitish slimy fluid slowly oozed through crevices in the ship's lining, perhaps some gallons in 24 hours, flowing, if not obstructed, into the bilges. This fluid, which was extremely fœtid at first, became less so after exposure to the air. Of course in a confined space it was very offensive. On the discovery of one of those leaks in the main hold, this

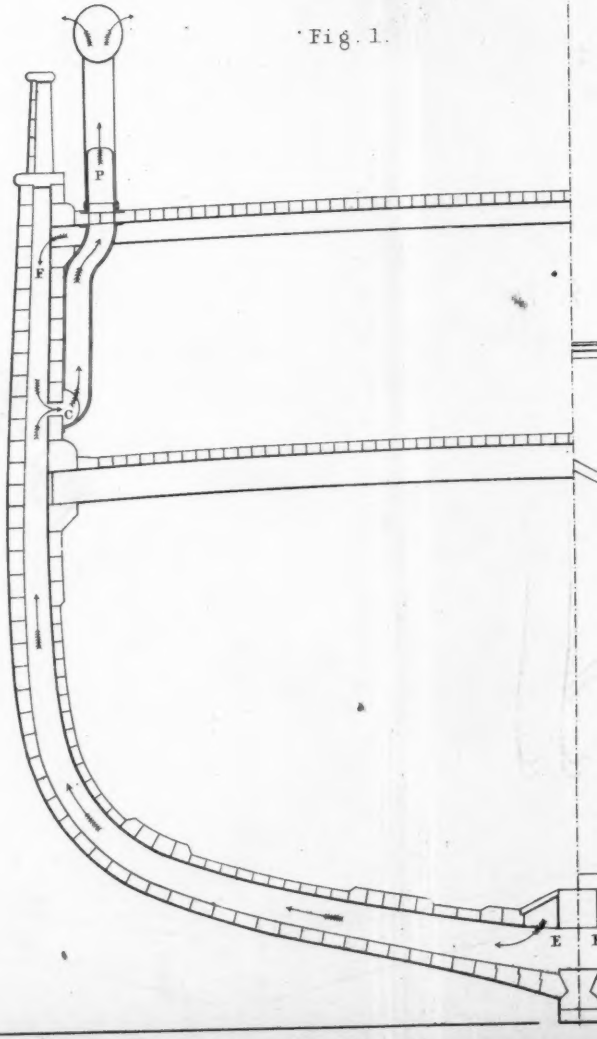
was cleared out, and the men employed in the work not only felt temporary ill effects from it, but I traced several cases of the peculiar disease to this cause directly; besides these leaks, we found in the hold and other accessible parts, that the timber spaces were mostly choked up with damp or wet decayed wood and chips, left by the shipwrights who built the ship, mixed up with other organic matters. In addition to these causes of air contamination, about fifty bucketsful of black mud were, on one occasion, found under the fore-magazine, and this produced injurious effects on the men who removed it. All these matters are fully detailed in my Medical Report for that ship during 1860, and noticed in Dr. Bryson's Statistical Report for that year. In my anxious endeavours to find a remedy for this state of things, I devised the plan of ventilation which I shall shortly explain, and, at the first opportunity, while serving as staff surgeon of the "Victory," I brought it under the notice of the Admiralty (together with other sanitary improvements), as being not only a highly desirable mode of ventilation for the benefit of the ship's crew, but also for the conservation of the ships themselves, by establishing a circulation of air through their framework. Their Lordships, with great liberality, authorised me to carry out these plans under my own supervision in several ships, and have lately entrusted me with the preparation, for their consideration, of General Proposals for the ventilation of all classes of ships.

Now the construction of ships according to the old plan really affords extraordinary facilities for ventilation; and by a simple arrangement, these channels or timber spaces, which have so long been allowed to vitiate the atmosphere of the between decks, can be converted into a most effective means for ventilating it. It will be observed that these timber spaces ordinarily have outlets, as I have before said, not only in all wooden ships, but also in many iron-cased ships, such as the "Prince Consort" and "Royal Alfred," above, over the shelf pieces (F) (Plate xxvii) into the hammock spaces, and below at the bilges (E). Now these are the most important points at which to exert our chief ventilating power; in the timber spaces we have a most convenient means of communication with all those parts ready made for us, and by using them as ventilators we accomplish another most important object, that of *their* ventilation, for which the merely passive circulation hitherto taking place was totally inadequate. The manner in which I utilize these channels is by constructing a longitudinal air shaft (C) over them at any *convenient* level. I prefer to place it over the list piece, which is one of the lining planks ordinarily left out when a ship is laid up, for the purpose of admitting a freer access of air to these timber spaces, and having a graduated communication into each. Now by this shaft we can command the entire ventilation of the ship. We have only to connect it into one or more vertical upshafts or ventilators, as at (P), and effect its ventilation by the best means which are available.

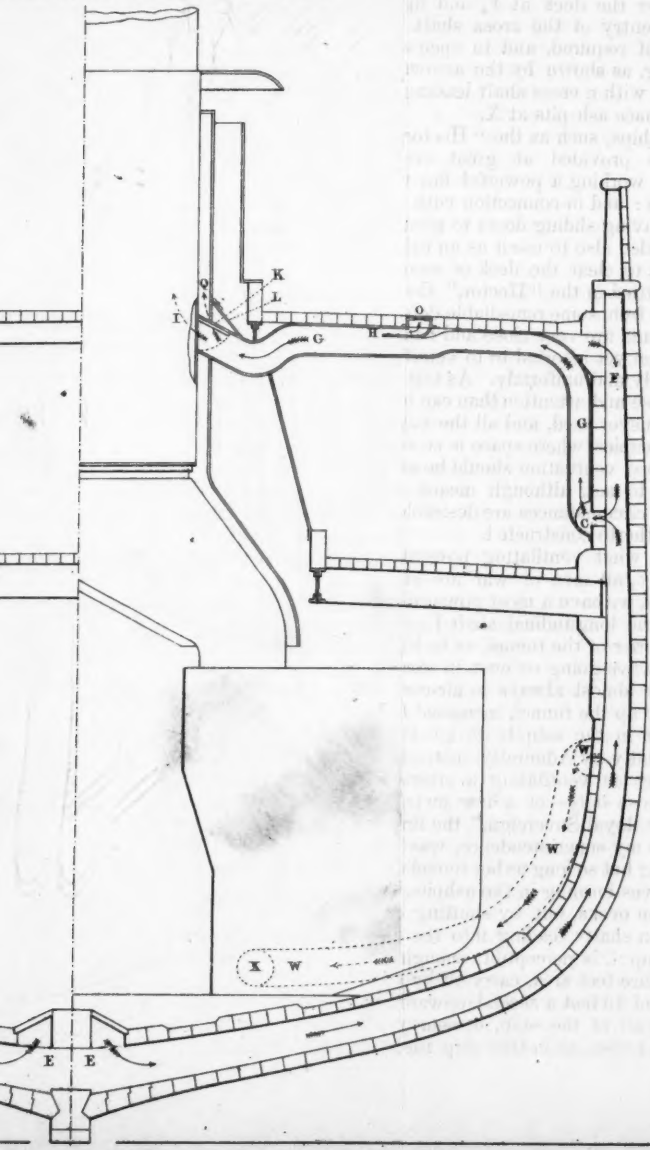
F. E., Fig. 1, Plate XXVII, represents one of the timber spaces laid open; these are at about two feet intervals, C, a section of its longitudinal shaft connecting them. G the cross shaft from it to the funnel, receiving also the deck-channel at O. On the sailing ship side, the

Section of half a Steam Ship, a
illustrating Dr EDMONDS

Fig. 1.



am Ship, and half of a Sailing Ship,
D^r EDMONDS system of Ventilation



J.R.Jobbins

long shaft communicates into an upright tube and cowl ventilator, the cowl turned from the wind. The course of the air current is shown by arrows, downwards under the deck at F, and upwards from the bilges at E. At I is the entry of the cross shaft into the funnel. Q is a valve to close this, if required, and to open a passage for the foul air up the funnel-casing, as shown by the arrows. W is another situation for the long shaft, with a cross shaft leading downwards and opening into one of the furnace ash-pits at X.

In some of the new iron ships, such as the "Hector" and "Valiant," special steam engines are provided at great cost of room and expense, for the purpose of working a powerful fan to force fresh air into the lower compartments; and in connection with it is a large shaft passing through them all, having sliding doors to give exit to the air so forced. I believe it is intended also to use it as an exhausting agent to draw out foul air, as well as to clear the deck of smoke; but it failed to act in this manner when tried in the "Hector," the only ship of the two in commission, probably from some remediable defect; but although this ship's lower compartments are very close and badly ventilated, the steam engine has never been yet resorted to to ventilate them. To be useful it should act invariably and uniformly. As this cannot be accomplished without more expense and attention than can be spared on board ship, the result is that it is never used, and all the expense of its construction and the space it occupies, where space is so valuable, is thrown away. As I have said before, ventilation should be as a rule self-acting and uniform, never ceasing to act, although means for increasing its amount under extraordinary circumstances are desirable, but by a simpler mode than by engines as hitherto constructed.

I now come to consider what ventilating powers we have at our command. In the first place, all men of war are steamships, and in the funnel of the boiler fires, we have a most powerful ventilator. It is only necessary to connect the longitudinal shaft I have described by a transverse one with the interior of the funnel, as in Fig. 1 (I), to create a self-acting ventilation, always going on even in some degree when no fires are burning, as there is almost always an air-current of from three to six feet a second passing up the funnel, increased to about ten when a few small stoves are put in the ashpits to air the flues, which is required to be done frequently by Admiralty instructions; and surely for such an important object as ventilating a crowded ship the consumption—if for this purpose only—of a few cwts. of coal per day is a trifling matter. The "Royal Sovereign," the first ship fitted with this ventilating shaft under my superintendence, was always noted as a very foul ship in the bilges; but so long as her funnel draft is accelerated by keeping a few small stoves burning in the ashpits, no smell whatever is discernible in the between decks, but by shutting off for a moment the valve in one of the main shafts leading into the funnel, the odour of bilge in the air passing up it, is perceptible enough. The two shafts being each of about $1\frac{1}{2}$ square feet area, carry off by discharge into the funnel, at the ordinary rate of 10 feet a second, upwards of 100,000 cubic feet an hour, of the foulest air of the ship, drawn, you will perceive, from its foulest source, the bilges, as in this ship the timbers are filled

in above. When steam is up, the velocity of discharge is from 20 to 30 feet a second, equal to from 200,000 to 300,000 cubic feet per hour.

A valuable auxiliary power for the ventilation of iron and iron-clad ships is the hollow iron masts with which they are furnished. These have a constant updraft, easily increased to a considerable extent by slightly heating their interior, either by a very small coke or charcoal stove, or even by a common lamp, or better still, by a system of lighting. I have lately proposed and tried very successfully on board the "Hector," in which all the chimneys of the lamps lead into a common tube, which discharges itself into the interior of the hollow iron mast, carrying off all their foul and heated vapours, and at the same time increasing the ventilating powers of the mast.

You will observe that I have placed ventilation by means of the masts and funnel in the first place; the reason I consider them as most valuable is, because they are self-acting, requiring no looking after; everything depending on attention is liable to constant interruption and derangement, especially at night time when ventilation is most wanted. Thus it is with windsails, these are useful enough for giving an occasional airing to parts of the ship they can be made to reach; the main objection to them is that they cease to act when they are most wanted, as during such calms as are experienced in crossing the line, when the ship, if under sail only, often lies motionless under a sweltering sun for days and even weeks. Tube and cowl ventilators are open partially to the same objection, but they are far more useful and act when very light airs are moving; used as down-takes, their action is partial, and may cause drafts to those men sleeping in their vicinity, who will close them up, while those remote are suffering for want of air; they require, moreover, constant attention which is a great dawback. Used in connection with a steam jet to create a powerful up-draft in calms, where only it is necessary, they are very effectual. By connecting all the air shafts of my ventilating system with a central ventilator, two feet in diameter, and furnishing this with a number of minute steam jets, supplied by the distilling apparatus which is now carried in almost all passenger ships, a most powerful and effectual means of ventilation is provided, available in calms, when it is so much wanted, and when there are no other means except those worked by machinery.

The action of this plan during the day is divided and diffused equally upon the bilges, hold, and the passenger deck in emigrant or troop ships; but at night time, when all the hatches below are closed, nearly its whole power is exercised upon the passenger deck, where, during the time people are sleeping, ventilation is most necessary.

By the liberality of Her Majesty's Emigration Commissioners, ever anxious to give a fair trial to any plan likely to add to the comfort and health of the emigrants sent out by them, three of their ships taken up about a year ago were ventilated under my superintendence on the plan which I have described. All the superintending surgeons reported most favourably of its great usefulness in keeping the air of the

between decks always sweet and pure, in lowering the temperature by carrying off much of the heated air, and of its salutary effect on the health of the emigrants. Children are always the first to suffer from the effect of bad air, and it was particularly remarked by Dr. Barry, Superintendent of one of the ships so fitted, and descanted upon by him lately in a paper read before the Royal Dublin Society, that not one child died on board the emigrant ship "General Caulfield," under his superintendence, during the voyage, and that the whole crew enjoyed a very high standard of health; thus tending to bear out my theory that a large portion of the diseases, both active and insidious, on board ships arises from endemic causes existing in the ships themselves, and its *preventible* nature by the means I have described.

In ships used as transports, such a system would be vitally important to preserve the health of our soldiers, during their tedious and trying voyage to a tropical climate, and I am glad to be able to state that the Admiralty, on the recommendation of Captain W. R. Mends, C.B., Director of Transports, have decided on testing its efficacy. The men sent out to fight our battles and maintain our empire abroad require all their energies to resist the unhealthy and deleterious influences to which they will be exposed on landing.

Having now described a very important means of ventilation, specially applicable to all wooden ships as well as to iron-clad ships, such as the "Royal Oak" and the "Prince Consort" class, I must now describe to you another important part of the system of ventilation I recommend.

The communication established by means of the side shaft with the upper atmosphere of the mess or sleeping deck, through the open timber spaces above the shelf pieces, will, if sufficient ventilating power is applied, suffice for the ventilation of this space. But in iron ships generally, and in many iron-clad ships, there are either no timber spaces at all, or if existing they do not extend high enough to communicate with the mess deck, as for instance in the "Royal Sovereign." In effect the ventilation of the between decks was always considered a very difficult matter, and numerous contrivances have been successively proposed, tried, and ultimately abandoned, either from experience proving their inefficiency, or from their requiring more attention, than it was found practicable or convenient to give them on board ship, where, as I have said before, the importance of ventilation was not sufficiently obvious either to Officers or crew. Above 130 years ago Dr. Desaguliers invented a blowing engine, which was tried on board some of our men-of-war, but failed in practical application, as it required constant manual labour to keep it in action, and there were no means of diffusing its action. Dr. Hales about the same time contrived another blowing apparatus, which was open to the same objection. A far more valuable invention was introduced by a brewer, named Mr. Sutton, in 1741, in which we have for the first time fire draft proposed and made available for ventilation, but his only ventilating power was the draft of the galley fire, and a pipe 6 inches in diameter was led from it to the vicinity of the well of the ship. Its action was, to a certain extent, very successful, and so long as the

galley fire was lighted the extremity of the pipe sucked in a certain quantity of foul air, which was discharged up the galley chimney. Now the area of the pipe being one-fifth of a square foot; at 10 feet a second velocity—a high estimate—this would give us only about 7,000 cubic feet discharged per hour, and even this amount of foul air being prevented—by its withdrawal—from contaminating the general atmosphere of the deck, was of great service.

Admiral Boscawen testified and wrote, "I cannot help thinking the air pipes fixed in the men-of-war of great service, preventing the scurvy by purifying the between decks." I need not point out how comparatively insignificant the draft of the galley fire on this 6-inch pipe acting on a limited area must have been, compared to that of a steamer's funnel alone acting on shafts—in the aggregate—at least 30 times as capacious, and whose action is diffused equally over and through the whole ship; nevertheless, Mr. Sutton's plan was for a time very generally adopted. I have not time to describe later improvements in ventilating ships, among others Dr. Reid has a very distinguished place, and his successful ventilation of the "Niger" and "Wilberforce" ships, for arctic service, indicate great scientific skill and experience. To ventilate the mess deck, the use of transverse hollow beams has been proposed, and if these could be constructed and connected into central shafts, in the manner I have described and carried out, they might be very efficient. It is some years since the idea first occurred to me of substituting for one or more of the deck planks, forming the ceiling of the deck to be ventilated, a hollow air channel, constructed of such materials as would make it as strong as the deck itself, and which, being immediately over the men in their hammocks at night, would receive the foul air almost directly it was emitted from the lungs, before it had time to mix with and contaminate the bulk of the surrounding air, consequently necessitating that successive portions of fresh air be constantly presented for respiration; and this brings me again to my assertion of the practicability of keeping up a healthy circulation of air in a very small space. I have before stated that the cubic space available for respiration on a ship's lower deck at night, when the men are sleeping closely packed together in hammocks, is incredibly small to those accustomed to consider its requirements on shore. I doubt if it is nearly 10 cubic feet for each person. Now these deck channels I am describing are admirably adapted for ventilating this space, and from the formation of a ship's deck, intersected with cross beams about a foot in depth, there are no other possible means for so effectually accomplishing this object; for, supposing an air shaft for this purpose could be carried along the deck under these cross beams, where it would be in every one's way, it would be too low to ventilate the space above it, as it would be in a line with the hammocks themselves; the only other means of acting upon this air space is that which I have before spoken of—through the openings into the timber spaces between the beams over the shelf piece—and which hitherto have only yielded an additional source of air contamination.

The mode of constructing these deck-air channels will be best understood by a reference to the sketch (Fig. 2, Plate xxviii). Possibly it has

Fig. 2.

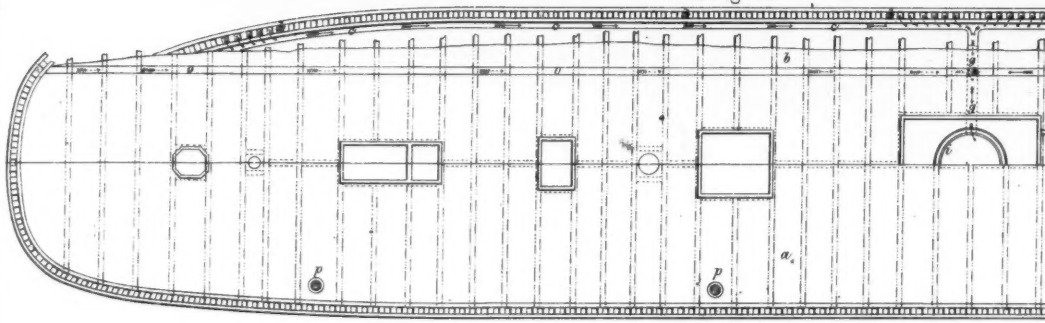
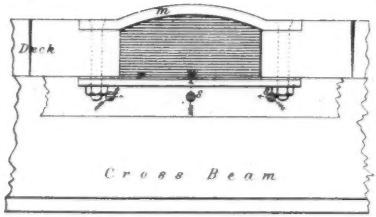
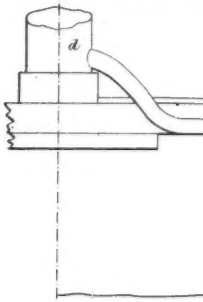


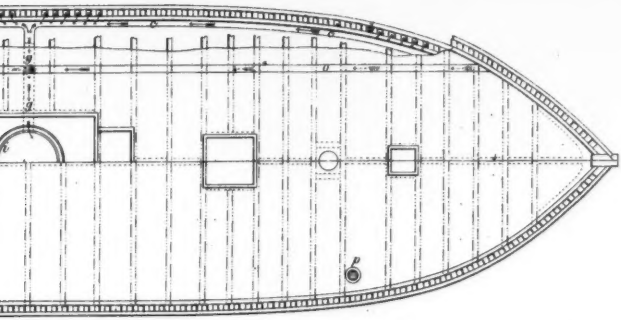
Fig. 3.



Section of the Deck Channel
m An Iron Plate covering the Air space, secured by Screws and Nuts at (s) into an Iron Bar at intervals beneath the Deck



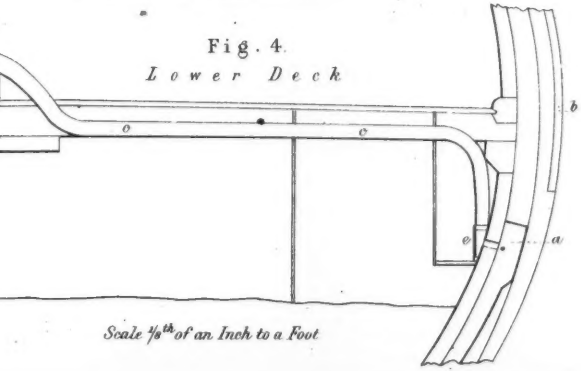
Scale



Plan of a Horizontal Section of a Ship at the Level of the Deck, a portion of which is removed on the Port side to shew the Longitudinal Shaft c and its communications with all the openings d d d as shewn by the arrows, o o o represent the Deck Channel of one side communicating at h by the Cross Shaft g into the Funnel i, p p p Tube and Cowl Ventilators for Sailing Ships

Fig. 4.

Lower Deck



Section at Main Mast

Communication of the Timber spaces, and their Ventilation by means of the Iron Masts.

Scale 1/8th of an Inch to a Foot

a. Highest part of Timber space
b. Iron Casing
e. Air Shaft communicating with Timber spaces or openings
c. Its communication into
d. One of the Masts

occurred to few persons who have walked on a ship's deck, to ascertain its thickness, unless we see it in the course of formation, which persons in general rarely have an opportunity of seeing, we have no means of judging of it. But a ship's deck is a very substantial structure; in a man-of-war it is composed of planks or timbers of four or four and a half inches in thickness, and from eight to ten inches in breadth. Now, if we replace one of those planks with a hollow iron channel of the same form, and if we can so arrange the harder material that one-fifth of it shall be equal in strength to the wood, we have four-fifths of the space it occupied available for a ventilating channel in the best possible positions, being an area of 32 square inches in the space of the larger planks, each channel equal to a tube of $6\frac{1}{2}$ inches in diameter. There are several modes of constructing these deck-channels. In the "Zealous," a half-inch thick iron plate overlapping the plank on each side about 2 inches, and slightly arched for strength, rising 1 inch in 12, covering in the space below it, is strongly screwed into the planks and beams, and is covered in underneath with thin sheet iron perforated with holes, their area regulated according to certain rules, to equalize its action. In the sketch you will perceive branch air-channels are made to diffuse the ventilating action—and here also we see the important part the iron masts are made to serve by their connection with these deck-channels as well as with the side shafts. As figures give us the best idea of degree and effect, I shall sum up the total ventilating power these will give us, that is without any means being used to increase it. Supposing, of course, the funnel to be raised and not covered over, and the masts, with their average up-draft of 6 feet a second, and taking also the funnel draft at the same low estimate, we must next estimate the capacity of our air-shafts, and these deck channels being, in the "Zealous," of 40 square inches area on each side of the ship, and having four outlets into the iron masts and funnel,—each outlet being of double the area of the channel, and being fed by the whole of its area on each side, constitutes, as it were, two branches, thus we have:—

Area of each outlet.			For both sides.	
80	× 4	× 2	= 640	≐ $4\frac{1}{2}$ cubic feet;

Sec. in min.		Min. in hour.		Area of sq. feet.		Feet per second velocity.		Cubic feet per hour discharged.
60	×	60	×	$4\frac{1}{2}$	×	6	=	86,400

As the cubical capacity of the lower deck, after deducting the space occupied by solid objects, is less than 40,000 cubic feet, we have the entire deck atmosphere renewed every half-hour, by a silent, self-acting, almost imperceptible process, causing no draughts or inconvenience to any one, acting more powerfully as the lower deck atmosphere becomes warmer compared with the outer atmosphere, and capable of being doubled in power, if thought necessary, by the use of small stoves in the lower part of the hollow masts, or other simple means; but as the natural up-current, by which the ventilation is

entirely self-acting, carries off 86,400 feet of impure air, or in other words, supplies the same quantity of pure air, this will give for 500 men 170 cubic feet per hour to each person, amply sufficient, under the circumstances, for healthy respiration, although, of course, in hot weather, this should be increased as much as possible by the means I have pointed out. In this estimate I have given the ventilation of the lower deck alone by the other part of the apparatus, as fitted in Her Majesty's ship "Zealous;" in addition, a still larger quantity of air is also drawn from the bilges through the timber spaces, thus removing what would otherwise greatly add to the impurity of the ship's atmosphere. Although I have sought to remedy by the means I have pointed out the evils necessarily arising from the crowded state in which men sleep on board ship, I do not wish it to be understood that I consider no change in this respect desirable. At night-time, particularly in hot weather, the men should be scattered as much as possible, and if sleeping in hammocks, there should be, at least, six inches between them at their broadest part, when the men are turned in; as the hammock-hooks are at present only 14 inches apart, they should be numbered, and the odd numbers assigned to one watch and the even numbers to the other; at sea the alternate hammocks would always be unoccupied, and in harbour, the second watch should lie upon the main deck in frigates and large ships, or hang up their hammocks over the guns. In the French Navy, I believe the men always sleep at their quarters when not in the open air. Of course, those men who are not in watches, too often miscalled idlers, and the boys should sleep in a part of the ship by themselves.

Having now brought under your notice the plan of ventilation for iron and iron-clad ships which I think the most convenient and effectual, I shall request your attention to some other matters connected with iron ships. There is a very general complaint made by men serving in them that they are cold and damp, and it is not a subject for surprise if they are so; of course, metal being a better conductor of heat than wood, the tendency to equalization of temperature with the external atmosphere is greater than in wooden ships; the dampness is more apparent than real, as it exists more upon the iron surfaces than in the air within the ships. Nevertheless, it is very disagreeable to see your cabin streaming with water condensed upon the iron surfaces of the ship's side, or dropping from the ceiling overhead, and this occurs whenever the temperature of the iron is colder than the atmosphere surrounding it; in reality, it relieves the atmosphere of its superabundant moisture. Precisely the same phenomenon takes place when we pour our iced wine or water into a glass, its outer surface soon becomes wet with condensed moisture, which thus manifests its presence otherwise unobserved. So it is in iron ships; an Engineer Officer, now serving in one of them, assured me that frequently he could scrape up water from the sides of his cabin with the hollow of his hand, and this water running down and wetting everything was a positive inconvenience; this, however, could and should be remedied by covering all internal iron surfaces with non-conductors, as felt under painted canvas, or lining them with wood. As there can be no decom-

position in the frame-work of an iron-ship, such as almost always exists, more or less, in wooden ships, I think they ought to be on the whole healthier abodes for sailors than wooden iron-cased ships, as hitherto ventilated; and I believe experience has shown this to be the case. To ventilate the close compartment of iron ships, standing ventilators are useful, whether as uptakes with the cowl turned from the wind, when a vacuum proportioned to the force of the wind is created, drawing air upwards; or as downtakes when the cowl is faced to the wind. The space on each side of the kelson being the main drain of the ship is a very frequent source of bad odours, especially in the vicinity of the pump-well; to remedy this, in the "Victoria," flagship in the Mediterranean, ventilated under my directions, in addition to the longitudinal shaft I have described, communicating with the timber spaces and ventilated by the two funnels, I had a passage formed leading from under one of the ashpits of the boiler fires to the pump-wells, and by also covering over the floor of the screw passage, which in the "Victoria" was continuous with the stokehold floor, a covered air space was also formed (this passage should be made continuous in all steam-ships, from the screw passage to the limbers forward), and a moveable communication being made into one or two of the ashpits, bringing the whole length under the influence of the funnel draft, this part of the ship is effectually and easily ventilated. In iron-cased ships, where the men mess on the lower deck, the coaling shoots, usually about seven of a side, are of great assistance in ventilating it, if properly contrived; the funnel casing should also be fitted with hinged-flap doors, to admit light when open, and, if high up, they ventilate powerfully. The hollow bitts, called ventilating bitts, also assist us if properly utilized.

All the available means of ventilation in a ship should be studied and properly economized. Iron ships and iron-cased ships have the additional advantage of iron masts, which hitherto, through the large man-hole cut in them, nearer the deck than the beams, have only carried off a large portion of the pure air which exists at that level, instead of being made available in the manner I have shown, to drain off the foul air. I must here beg leave to allude to a calamity, viz., the burning of the "Bombay," in which the rapid spread of the fire was attributed to there being too much ventilation in the ship; and there can be no doubt that owing to one of the modes of ventilation adopted, such really was the case, but only after the fire commenced. I venture to affirm that had the ship been ventilated on my system, as I have described it to you, the spirit room might and should have remained quite isolated from all parts of the ship, in fact every yard of the ship's length, if divided into compartments can be, and is, separately ventilated with this additional advantage, that the whole is under such perfect control that the ventilation can be instantly stopped at will, by closing the valves or cutting off the main trunks. This practice of connecting all the store-rooms with each other laterally by gratings, can only equalize their atmospheric state, however foul, and, as in the case of the "Bombay," facilitate the spread of fire should it break out, without doing any real good. It is not unusual, too, to have gratings for the

floor of the cockpit, where the midshipmen sleep, between it and the screw passage, which is below it, and where there is the foulest air in the ship from the after bilges. I could point to numerous other instances of unscientific, ventilation so-called; often where there is very great show, but little real good is effected, and then we hear the cry of too much ventilation when the fact is far otherwise.

In conclusion, you will, I am sure, agree with me that it is far more important, and fortunately it is far easier, to prevent disease than to cure it; it is especially the duty of all scientific men connected with the Services, particularly those who are entrusted with the construction of our men-of-war, whether for general service or for the conveyance of our troops to foreign stations, to neglect no means which skill or science can suggest, or experience has shown to be useful, not only to remove all causes which might have a tendency to deteriorate the atmosphere of a ship, and which I have shown do exist to a degree not generally suspected, but also to provide for ventilation of the ship's crowded decks in such a manner that no one shall be incommoded by it; and that the air, so soon as it becomes vitiated by the men's breathing or by contact with their bodies, shall be at once withdrawn from their vicinity; this can be only effected by acting upon it in the high level, to which such foul air at once rises, before it has lost the properties to which it owed its ascensional power, heat and moisture. You will readily see how the first object is accomplished by converting the timber spaces, ordinarily sources of air contamination, into ventilating channels; and how, in iron ships, the deck ventilators, on the hollow plank principle, give us the most effective mode of accomplishing a direct and convenient communication with those air spaces which we specially require to act upon.

I hope I have made clear to you what a valuable means for ventilating iron and iron-clad ships we have in the funnel and in the iron masts, used in connection with the system of air shafts I have described; and how through them, their ventilating power is economized, drawing off only the foulest air in the ship through foul air sources, and at the same time necessitating, through atmospheric gravitation, the introduction of an equal quantity of pure air into the ship, by a continuous self-acting process, quite unaccompanied with those cold currents of air, which too often punish the few for the benefit of the many.

These, gentlemen, are the main points I wish to bring under your consideration. Our iron-clad ships have not yet been tried sufficiently in hot climates to enable us to judge of their comparative healthfulness; but so far, the reports are not very favourable, even from the Mediterranean. What would be their sanitary state if serving in the tropics during a yellow fever epidemic we have no experience to judge from; all that can be done is to make their ventilation and sanitary state as perfect as possible, and we can do no more. When epidemic disease breaks out, whether in a ship or on shore, no expense or exertion is grudged which offers even a chance of circumscribing or diminishing its ravages, one tithe of which expended in measures of precaution would have sufficed in all human probability for its prevention. When the ravages of fever have commenced in a ship, it is too late, and it is

always dangerous while the crew are on board, to clear out the holds and to seek for its causes; in most cases it is impossible to reach them.

Every ship before proceeding to a foreign station, especially if within the tropics, should be sanitarily inspected to ascertain, 1st, that there are no causes existing within the ship which might generate malaria, under the influence of tropical heat, such as accumulation in the timber spaces or any tendency to dry rot; and, 2nd, to ascertain that every practicable provision has been made for ventilation on scientific principles, so as to effect a constant but imperceptible renewal of the air of the between decks by removing the foul air, by some system which must be self-acting, and not dependent upon the uncertain wind or the equally uncertain attention of others. Of course the utmost amount of lateral openings through the ship's side is indispensable, for air as well as for light, by means of ports or scuttles, to be kept open whenever practicable, in hot climates; but at sea, ventilation must be independent of them. Where due care is bestowed on all these important points, and the ship herself is kept free from all malarious causes, I believe that sailors might enjoy a high standard of health, compared with other classes, not only in wooden but also in iron and iron-clad ships.

The CHAIRMAN: I am sure that the meeting must feel that the question which has been brought before us by Dr. Edmonds is one of the very greatest importance, especially with regard to the health of the seamen employed in our ships; and naturally the new construction of our vessels necessitates a greater care in ventilation than was formerly required. I think the one great point in all Dr. Edmonds' proposals is this, that he applies the most simple means for ventilation; and instead of applying fans or other complicated arrangements which are liable to get out of order and to be neglected, by availing himself of the funnel, the masts, and other spaces, he produces a current through the ship, ventilating it most fully, without really interfering in any way with the internal economy of the vessel. I have myself seen the air shaft which Dr. Edmonds has spoken of on board one of the vessels, and you would not suppose it was there; and if it fairly performs all that has been described, there can be no question that it is a most efficient way of ventilating the ship, and of carrying away the foul air which must necessarily be concentrated above the men's heads when they are sleeping, as naval men know they do, close to the beams. I am sure we all feel grateful to Dr. Edmonds, and I am sure the Admiralty have placed in very good hands the ventilation of our ships, for he seems to have thoroughly studied the subject, and to have carried it out in the most practical manner.

Evening Meeting.

Monday, May 1st, 1865.

REAR-ADMIRAL R. COLLINSON, C.B., in the Chair.

NAMES of MEMBERS who joined the Institution between the 24th April and the 1st May, 1865.

ANNUAL.

Gordon, L. G., Lieut.-Col., Royal Engineers. 1*l.*
Lane, J. V., Assist.-Surg., 4th King's Own.
Browne, James, Lieut., 94th Regt.
Blackett, L. F., Lieut., Rifle Brigade. 1*l.*
Travers, Jas., Brig.-Gen., Bengal Army.

THE NAVIGATION OF THE RIVER HOOGHLY, AND THE PROPER MEANS TO BE ADOPTED FOR ITS AMELIORATION, ESPECIALLY IN REFERENCE TO THE DANGEROUS JAMES AND MARY SHOALS.

By W. A. BROOKS, Esq., C.E.

THE state of the river Hooghly, which has been for so many ages the almost sole outlet for the commerce of the richest districts of India, embracing an area of above half a million of square miles of land, is surely an object well worthy of the deepest attention.

Far different at the present day is the demand for accommodation for commercial interests, from that which existed when India was subject only to her native princes, and the little trade which was carried on was principally by small coasting vessels, which passed with ease over the shoalest parts of the navigation of the Hooghly. Those shoals now throttle the trade of the port of Calcutta; and the well-known and dangerous shoals, called the James and Mary, entail annually a greater charge upon the trade of the port than would suffice to remove them. Ships of large draught of water can only pass over them at or about the period of high water, rendering it therefore

necessary for them to bring up in their vicinity on their voyage down the river, in order to pass with safety at the proper time of tide.

It is thus that while a single day often suffices for a ship to sail up to Calcutta with a flowing tide, she is usually compelled to take two or three days before she is able fairly to get to sea out of the Hooghly. Still, the Hooghly is a noble river. From the fairway buoy to "The City of Palaces" the various channels seldom possess less than a depth of five fathoms at low water in the straight reaches, and from seven to ten where the stream ranges along concave shores; and in a well regulated state of the river there would be nowhere found less than five fathoms at low water; the existing shoal places being met with only where the stream is allowed to abruptly change its course from one bank of the river to the other, or where the navigation, from being divided into several channels, in lieu of being confined in one, loses necessarily in depth.

Shoals are also encountered where the course taken by ships changes from one of those channels into that of another, owing to the conservators of the port having lighted up and buoyed out a mere lateral or flood-tide channel, which is destitute of any deep-water passage into it from above. Thus ships, after having safely reached the Saugor roadstead, find their further passage up the river barred by the vast bank of sand which separates the Saugor roadstead from the western or main channel of the Hooghly, and can only get into that channel by passing over the bank at the slack places or channels, which are buoyed off through it. The southernmost of these swatchways, called Lloyd's Channel, has barely a depth in it of two fathoms at low water; and the Bedford, or northernmost, has generally only the same limited depth. These channels would therefore be impracticable for ships of large draught of water but for the lift of tide of from 12 to 14 feet during spring tides, and from 6 to 9 feet during neap tides.

The resolution to light up and buoy out the noble roadstead abreast of Saugor Island, in lieu of the main or western channel of the Hooghly, has thus entailed upon the navigation of the Hooghly the difficulties of passing either by Lloyd's or the Bedford channels, through that vast bank of sand and mud which will at some future period form part of Saugor Island; because, like the latter, its shoal condition is due to the deflection of the ebbing waters of the Hooghly by the trend of the left bank of the river above Saugor Island, thus forming a vast eddy abreast of the latter, which forms a place of deposit for the alluvions of the Hooghly, which are only partially removed by the action of the current of the flood tides. Having regard to the increased navigable depth which is required for the trade of Calcutta, as well as the reasonable probability of a still further diminution of the present navigable passes called "Lloyd's and the Bedford Channels," owing to the silent operations of nature, it will probably not be long before the Trinity House of Calcutta will take as much pains to effectually light up, and buoy the main or western channel, as they have that of the eastern one to Saugor roads; a more direct and deeper navigable channel will be the result, and ships will seldom experience the necessity of bringing up to anchor to wait for the tide, as they are now

so often obliged to do in Saugor roads. It is desirable also to close up the channel between the left bank of the Hooghly and the north point of Saugor Island, so as to concentrate the whole power of the currents of ebb and flood tides through the western or main channel, a measure which will also have the effect of ameliorating the condition of the navigation of the channel above Saugor Island; and this is probably all that is at present practicable towards increasing the safety and depth of the navigation through the estuary of the Hooghly.

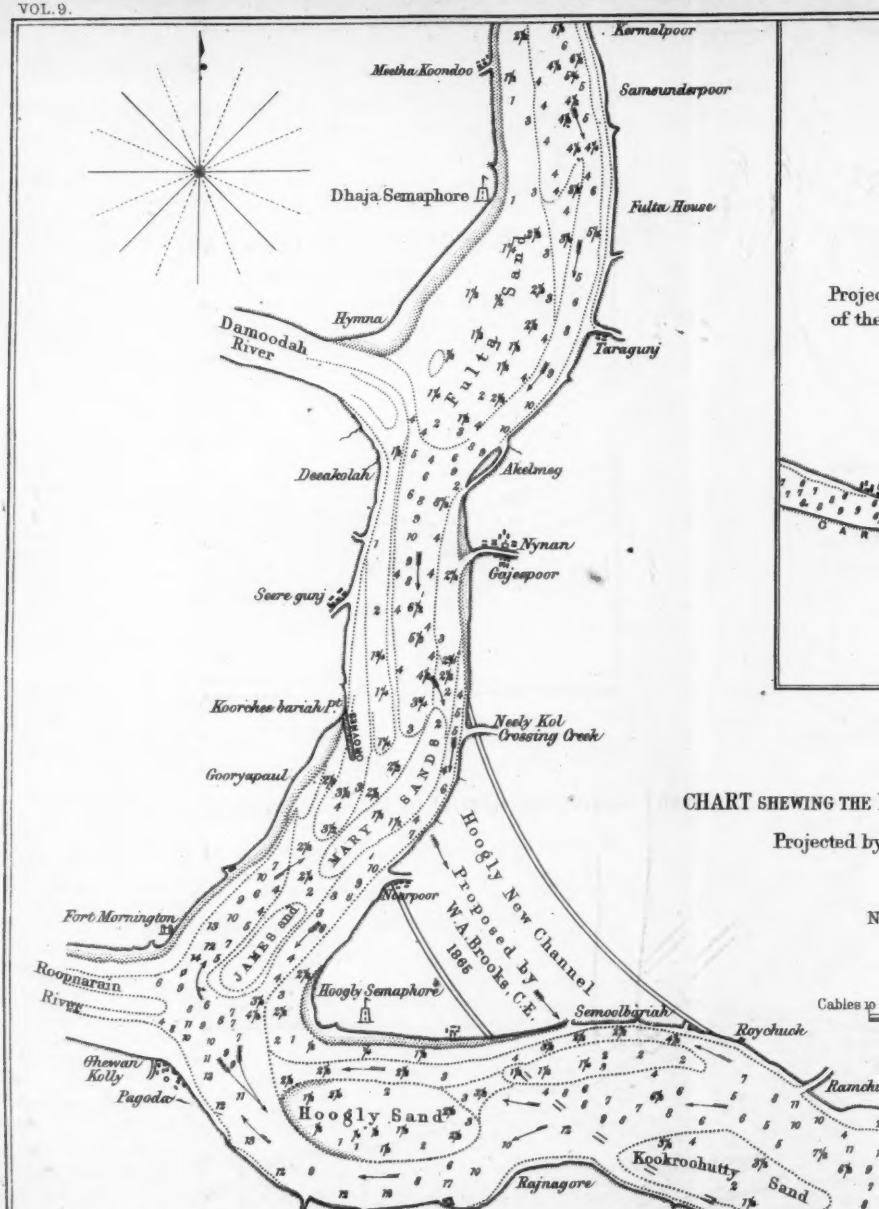
Higher up the river we have the encouragement of the good results produced by that natural embankment which has been produced by the deposit of alluvial matter on each side of the channel of the Hooghly, leaving nothing for man to improve upon in the course of many miles of its noble navigation. Thus from Currie's Docks, on the right bank of the river abreast of Calcutta, to 21 nautical miles below "the City of Palaces," a fine channel exists, capable of being navigated at the lowest state of the river by ships of the largest draught of water; and this channel extends for a further length of 13 nautical miles, or to the upper end of the James and Mary shoals, only broken for a short course at three places by the five-fathom channel being reduced to $3\frac{1}{4}$ fathoms at low water by the crossing of the stream from the right bank of the river to the left bank at Allumpoor; by another similar crossing at the Brool Semaphore, from the left to the right bank, but with still as much as $4\frac{1}{4}$ fathoms at low water; and lastly, by a shoal abreast of the Dhaja Semaphore, where the current of the ebb crosses from the right to the left bank, but with happily the same depth of $4\frac{1}{4}$ fathoms at low water.

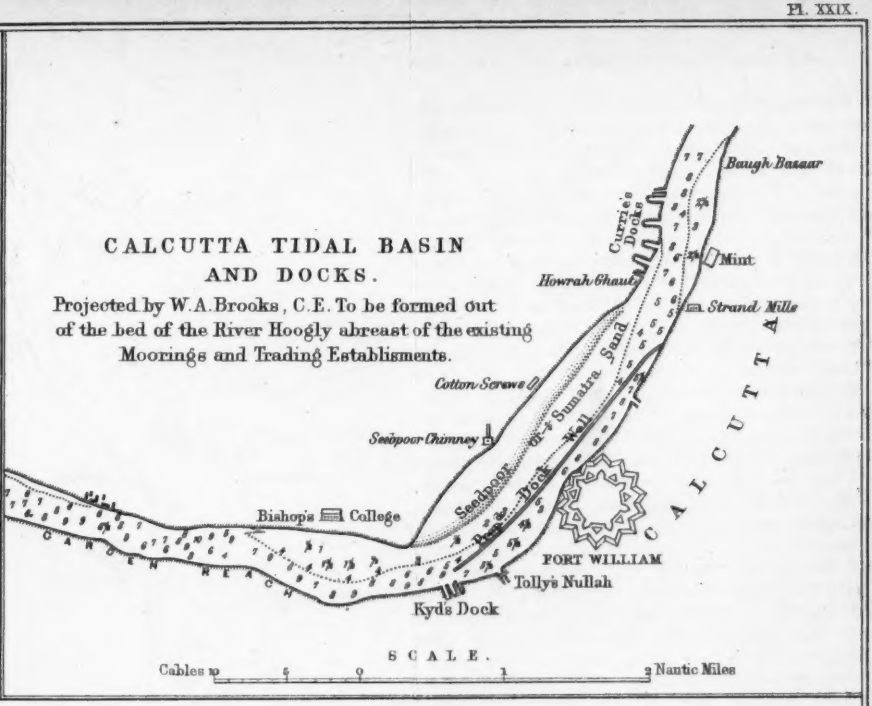
The navigation over those three shoals is also unattended with any great difficulty, and therefore while dangerous shoals remain, such as those of the James and Mary, it is evidently proper to concentrate every available resource on the rémoval or clearance of the latter.

The James and Mary shoals consist of what may be properly designated a maze of shoals, varying in form and depth with every change of the condition of the river as affected by the preponderating influence at the time of either the freshes or the strong flood tides of the south-west monsoon. This much may, however, be depended upon, as regards the influence of the pure tidal currents, that in no case will the latter be found capable of maintaining permanently deep or continuous channels; such will always be found to be dependent upon the current of the ebb, or upon the channel being directly open to and occupied by the natural backwater or drainage of the country.

The object which should be steadily kept in mind by an engineer charged with the improvement of a navigation is to seek to lead the flood currents into the same channel which is taken by the ebbing current; and this can always be effected, although wherever there is a great difference between the period of discharge of the ebb over that taken by the flood current, the latter will, at the early part of the flood, force its way along the shores, and particularly on the convex side of the channel, where it meets with less resistance from the current of the ebb.

On the examination of the chart (Pl. xxix) where the River Damoodah


Kermalpoor
Mootha Koondoo
Samsunderpoor
Dhaja Semaphore
Fulta House
Fulta Sand
Hymna
Damoodah River
Taragunj
Decakolah
Akelmeg
Nynan
Gajeepoor
Seere gunj
Koorches bariah Pt.
Neely Kol Crossing Creek
Gooryapaul
MARY SANDS
Hooghly New Channel Proposed by W.A. Brooks, C.E. 1845
Kaerpoor
Fort Mornington
JAMES and
Roopnarain River
Hooghly Semaphore
Semoolbariah
Raychuck
Cables 10
Sheevan Kolly
Pagoda
Hoogly Sand
Kookroohutty Sand
Rajnagore
Bangah gorah
Kookroohutty
CHART SHEWING THE
Projected by
N



IEWING THE IMPROVEMENT OF THE NAVIGATION OF THE RIVER HOOGLY.

Projected by W.A.Brooks, C.E. abreast of the James and Mary Shoals.

Note. *The Soundings are in Fathoms at Low Water of Spring tides.*

J.R.Jobbins.

falls into the Hooghly, we find that the combined currents produce a noble and central deep-water channel for two miles below, and that this channel only begins to shoal as the direction of the ebbing current through it feels the influence of the trend of the right bank towards the point of Koorchee-bariah, by which it is thrown towards the eastern or left bank of the Hooghly, abreast of Neely Koll, or Crossing Creek. The current, in thus crossing so abruptly from the right to the left bank, gains in breadth, and consequently loses in depth; and in consequence of this crossing, the available depth of channel is barely $2\frac{1}{4}$ fathoms at low water, in lieu of from 5 to 9 fathoms, which is found in the channel above the shoal of the James and Mary. The current after thus crossing to the left bank ranges along that shore, and, finally, at the lower end of the reach, again crosses over towards the right bank, nearly opposite the mouth of the Roopnarain river, but in this case the depth is usually greater, or amounts to about $3\frac{1}{4}$ fathoms at low water, because it is here subjected to the useful scour or discharge from the Roopnarain river, which, as in the example above of the Damoodah river, has the effect of deepening the navigation below its junction with the Hooghly; at the same time it must be admitted that the Roopnarain discharges its waters into the Hooghly so abruptly, that the dangers of the navigation of the Hooghly through the James and Mary shoals are greatly increased: no doubt can also arise as to the prejudicial effect produced by the flood tide being allowed to flow freely up the channel of the Roopnarain river, and to only find its course up that of the Hooghly by an abrupt and tortuous direction.

It has been shown that the trend of the shore of the right bank of the River Hooghly, below the mouth of the Damoodah, has the effect of throwing the current of the ebb towards the left bank, and thus also forming an eddy or still-water abreast of the right bank below Koorchee-bariah point, as far as the mouth of the Roopnarain river, and thus the whole of that part of the bed of the river would have consisted of dry banks, or very shoal water, but that a large portion of the deposit of sand on every ebb tide is swept away by the strong run of the flood tide over it from out of the Diamond reach of the Hooghly, and thus is scoured out the channel along the right bank of the river between Fort Mornington point, at the mouth of the Roopnarain, and Koorchee-bariah point. This flood-tide channel has 14 fathoms at low water at its lower end, and $2\frac{1}{2}$ fathoms at its upper end, where it falls into a pool which is made by the waters of the Hooghly, when the river is in a state of inundation. A second bank of $2\frac{1}{2}$ fathoms has afterwards to be crossed to reach the main channel of the ebb. It is a well-ascertained fact, that this western channel or gut is always opened out by the strong flood tides of the south-west moonsoon.

The main features of the navigation of what may be termed the region of shoals of the Hooghly consist therefore in the ebb and flood occupying different channels, each alternately crossing at nearly the centre of the reach between Koorchee-bariah on the right bank and Neely Koll, or Crossing Creek, on the left bank.

The remedy for this evil would appear to be found by the simple, although expensive process, of straightening the navigation by boldly filling up the bight or concave portion of the channel abreast of the left bank of the river between Nynan and half a mile below Noorpoor, thus forming a new foreshore as per blue line drawn on the chart. Such a work would have the effect of securing away the point of land at Koorchee-bariah, and a nearly straight and safe navigation would supersede the very dangerous one which now exists. The flood and ebb currents would almost entirely pass over the same bed.

The sole remaining question to be now considered is whether the execution of such a work, the groining up of this left bank, which has heretofore been proposed (at least the principle of the work, by the proposition "to construct a groin or spur at Crossing Creek") is such as would produce the greatest possible benefit to the navigation if carried into effect? The result of such an inquiry must be against such a plan, because it would be an imperfect one. It would still leave a very tortuous navigation round Hooghly Semaphore point, between the James and Mary and the Diamond reaches; but, above all, it would, as at present, leave the strength of the flood-current to set up the Roopnarain river, in lieu of the Hooghly channel above Diamond reach.

The relative directions of the Hooghly and Roopnarain channels above the Diamond reach are as injurious to the former as beneficial to the latter; and on this account the lower part of the channel of the Roopnarian river presents an extent of channel beyond that which would be due to it by reason of the amount of drainage or natural backwater which passes down it.

To groin, or fill up the bight on the left bank of the Hooghly above Diamond reach, would, therefore, be to leave difficulties in the navigation which might be removed by the adoption of a simpler and, it is believed, much less expensive plan, or by the formation of a new cut or channel across the neck of land which lies on the left bank between the James and Mary and the Diamond reaches, as particularly described on the chart. The right bank of this new cut will be concentric with the trend of the present right bank of the Hooghly, between the mouth of the Damoodah river and Koorchee-bariah point, and also the trend of the right bank of the Diamond reach below the point of Rajnagore.

To effect this great change, which will allow the streams of the Hooghly and Roopnarian to form easy connections with the Diamond reach, and altogether get clear of the dangerous navigation through the James and Mary shoals, it will only be necessary to make a cut of 2,240 yards in length, about one mile and a quarter, which, if broken into, just before the period when the great land floods commence, will, from the shortness of the new course, become rapidly the Hooghly navigation. The narrow cut first made on what would be the concave shore, would, in a few days, become a broad and deep channel. It would be advisable to guard against too deep a scour by facing the new concave bank, and possibly it might be advisable to construct a groin, at Koorchee-bariah point, concentric with the same shore of

the new cut, to more rapidly convert into land what now forms the principal portion of the sites of the James and Mary shoals.

The whole of the works necessary to effect this improvement of the navigation, irrespective of the purchase of land, would not cost £200,000.

Having, I trust, read nature's book correctly, in this my description of the features of the navigation of the Hooghly, I purpose now to submit to your investigation those views or theories which have already been propounded to the public on the same subject, for it could not be otherwise than that the dangerous navigation of the Hooghly has often been discussed.

Thus one author on the subject, and who is entitled to respect on account of the nautical information which he undoubtedly possesses, has told us that it is the influence of the Damoodah current which has led to the formation and maintenance of the James and Mary shoals; and the remedy proposed by that gentleman, and by several who have taken the same view, is "to divert the channel of the Damoodah from its present embouchure above the James and Mary shoals, and turn its waters into the Roopnarain river by a cut of four miles in length, from near Bagnan." To the above a reply has been given, where, in this paper, I have already shown that so far from the Damoodah having done any harm, it is proved to be of great service to the navigation below its junction with the Hooghly; and there is the further objection to its diversion into the Roopnarain, inasmuch as that measure could not be carried out without injury to the channel between its present embouchure and that of the Roopnarain, because of the abstraction of a large portion of the backwater which now keeps that channel open. It is said that in ancient times the waters of the Damoodah formed a junction with the Hooghly above Calcutta, and surely a restoration in that direction would be a more consistent course to adopt.

Another author, who has given his views professionally on the same question, as to the cause of the formation of the James and Mary shoals, attributes the same to "the strong ebb tide from the Roopnarain checking the Hooghly current".

To this theory an objection has been already offered in this paper, where I have shown that as the only effect of the ebbing current of the Roopnarain can be in sweeping away part (the lowermost margin) of the James and Mary sands, the current of the Roopnarain must be quite innocent of being the cause of any deposit or formation of sand on the sites of the James and Mary shoals; and this must be manifest when it is borne in mind, that while the water of the Roopnarain debouches into the Diamond reach below, the waters or current of the Hooghly are also taking the same course, and, in fact, the direction of the channel in the upper portion of the Diamond reach is the resultant of the two forces or discharges from the channels of the Hooghly and Roopnarain.

The Roopnarain current could only cause a deposit in the channel of the Hooghly above the embouchure of the Roopnarain, provided still water existed in the Hooghly above, a circumstance which can never

occur. By still water I mean comparatively still water. Thus supposing the rate of discharge of the Roopnarain very greatly exceeded that of the ebbing current of the Hooghly, the course of the latter might be diverted more towards its left bank, and partial slack water formed at the point of land immediately above the Roopnarain, but such is not the case, and the same is proved by deep water (14 fathoms) being found there, even at low water.

A notice of the Hooghly can hardly be considered satisfactory which omits a consideration of the necessity which exists of providing dock or still-water accommodation for the valuable class of ships which are now so exposed to disasters while moored in an open stream, which, in its inundated state, runs with the fearful velocity of six nautical miles an hour.

It must be evident that no moorings can be relied upon when they are subject to the shock of even a single heavy ship coming down upon them with so great a velocity.

It has been proposed to construct docks out of the land, on the left, or Calcutta bank, above the city; and, doubtless, such a work is practicable, but to give ample accommodation to the shipping, as well as to the country boats bringing goods, the acreage of the dock must be of great extent; but, above all, will be found the difficulty of providing easy, and safe access to such a dock during the period of inundations.

Having regard to these objects, as well as the convenience of the existing trade and shipping establishments, surely it would be more judicious to give the preference to the system of providing the required accommodation out of the present channel, without disturbing the vast vested interests on the shore of the city of Calcutta; as was done in the case of the construction by me of Northumberland Dock, in the Tyne, a few years since, where 70 acres of the stream were enclosed by a river embankment, and a dock was formed abreast of numerous staithes, at which above a million and a quarter of tons of coals were then annually shipped, and this, too, was done without stopping that valuable trade for a single day, and the new channel was simultaneously scoured by the current out of the maze of shoals which it displaced.

It may here be observed, that at all the great northern docks for shipping coal, the use of lockage is, in practice, dispensed with as much as possible.

The tide is allowed to freely enter when it has reached the level at which ships are water-borne in the docks, the gates being only closed to retain sufficient water to float the ships; but, inasmuch as in this great tidal basin or dock, projected by me abreast of Calcutta, the depth, even at low water, is ample for that purpose—ranging, in fact, from four to eight fathoms, it will not be necessary to provide entrance-gates or locks.

A space would be left open at the lower end of the dock of 450 feet in width, between the dock embankment and the shore, through which entrance, ships would freely sail on the flood or ebb tide, and also during the inundated state of the river, when they are able to make way against the current. On approaching the dock entrance, they would fall

into an easy tide, and at once pass freely up the dock to the wharves to which they are destined.

It is also proposed to leave another entrance, if required, through the body of the embankment for the admission of country boats. At the upper end of the dock sluice-gates will be constructed, to give the power of scouring away any accumulation of silt within the dock, which would be brought in by the flood tides.

This northern barrier would not be closed until after the long river embankment has been completed.

During the period of inundation, it would not be necessary to make use of the sluices, because at that time there would be comparatively little deposit, as the water in the dock would be still, or nearly unchanged; in fact, its level would only vary with that of the floods. The current outside, raging along at the rate of six miles an hour, would bear with it those vast alluvions with which it is at such times charged.

An accumulation would take place near the entrance, but the area of the deposit would be so limited that it could readily be kept clear by dredging, the annual outlay for which would be small in comparison to the returns necessary to meet the great charge which would be entailed by the construction of locks and gates on the indifferent foundation which the bed of the Hooghly and adjacent land everywhere affords; to say nothing of the greater facilities to trade which would be afforded by free ingress and egress without that delay which takes place in passing numerous vessels through gates and locks.

Without going minutely into the calculation of either docks excavated out of the land, or, as proposed by me, formed out of the bed of the river, it may be safely assumed that, without the purchase of land, a dock of only 25 acres, made out of the ground above the city of Calcutta, would cost more than one of 220 acres, if the latter were made by enclosing a portion of the bed of the Hooghly.

One great recommendation of the present scheme is, that it would not disturb the existing trade, or interfere with local mercantile establishments, and the expensive moorings which have been laid down.

The plan shows an alternative dock, of 205 acres, abreast of the northern division of Calcutta, between which dock and the Great Indian Railway a ready connection might be made by the bridge over the Hooghly, which is about to be constructed by the Railway Company.

Although the works proposed by me would, probably, answer all the requirements of the trade of Calcutta, in the simple form of a great tidal basin, nevertheless, it is quite practicable to convert the same into a floating-dock by the construction of gates at the south end, and founding them upon a thick bed of concrete.

Before you is a plan of Northumberland Dock, in the River Tyne, which has been referred to in this paper, and it will be seen that it appears as if traced out as an example for a work to be executed in the Hooghly, abreast of Calcutta, so precisely similar are the relative features of both sites, the advantage being, however, in favour of the Hooghly; because the site of the long embankment or river-wall in

the Tyne had to be constructed on a bed of sand, which was not penetrated through by borings carried to a depth of 60 feet below low water of spring-tides.

The CHAIRMAN: The subject which Mr. Brooks has brought before us to-night appears to me to divide itself into two sections. There is, first of all, the improvement of the lower part of the Hooghly in that particular crossing where the Damoodah river interferes with the navigation; the other portion relates to the construction of docks for the accommodation of shipping opposite to Calcutta. We shall be glad to hear any observations on the subject, and I hope the discussion will follow the course taken by Mr. Brooks, who began at the lower part of the river, and then passed from the lower part of the river to the upper.

Captain FISHBOURNE, R.N., C.B.: I think the subject of rivers, and the way in which they can be improved, has been too much overlooked. I fall very much into Mr. Brooks' views, though in some respects I differ from him; inasmuch as he said the effect of this current could not produce the James and Mary shoal. Now the effect of the flood coming up, meeting with the current coming from the Roopnarain is, that the flood is checked, and the moment it is checked in its flow upwards, there is a deposit which forms the James and Mary. Of course, that will not be very much. I quite agree with Mr. Brooks, that cutting a passage from the Damoodah river into the Roopnarain would be fatal, and make the shoal worse than it is at present. A necessary consequence of the former river coming in where it does, is to join the current coming down, the result of which is to produce the straight and strong current which now keeps the channel open, as shown in the diagram. Cut that off, the current from the Damoodah, and the main stream would shoot over against the right bank, and then over to the left, from which there would be a succession of transverse currents, which would create an increased number of shoals; it would also decrease the rapidity of the current, and the volume of it by the amount of that river, and besides the alteration of the direction of the current, it would tend to increase the difficulties of the James and Mary shoals. Now, let us suppose the effect of this increased current. We see that an evil would have arisen. If the cut were made, the current down would be increased. The effect would be this: the flood coming up would meet an increased down current; it would be resisted more than it is now, and it would bend round more than it does at present, and make the passage more intricate. I concur in Mr. Brooks' view as to the advantage of a new cut where he proposes it should be made, and do not think the cost would be great. I remember seeing a railway viaduct over a river upon which a great deal of money had been spent, because it was being continually undermined by the river, and they had to put in buttresses and all kinds of things to support the bridge. The engineer came to look at it. He saw where the stream struck, and he ordered some cart-loads of stones to be thrown in at that point. The result was that the stream was shot fair through the bridge, and the necessity for any further buttresses and props was rendered unnecessary. A groin at Koorchee-bariah would tend to turn the river over into the new direction, after the cut was opened, and of throwing the whole current straight through it; so groins in different parts would straighten the course, and would of course help to deepen it in the same way. It is a very unpleasant passage over the shoals at the present moment. Generally speaking, I agree with Mr. Brooks, and I feel, perhaps even more strongly than he does, that it would be fatal to the main river to change the embouchure of the Damoodah; besides which it would be a great expense, inasmuch as the distance is four miles instead of one.

Mr. BROOKS: That would exactly be the effect which Captain Fishbourne describes; the stream would strike on the right bank, and then rebound again.

A MEMBER: What is the width of the cut you propose?

Mr. BROOKS: A mile and a quarter. I propose merely to cut one-third through in breadth; it will soon tear all the rest away, and perhaps cut three or four branches all across the other part of the channel, but care must be taken to have the concave shore well protected, otherwise on that side it would get too deep, and would go back round to the westward.

General BOILEAU, R.E., F.R.S.: The James and Mary shoal has been the great

bugbear of the Hooghly river for half a century. I have known it for 45 years, and it is still the same dangerous shoal; but really I believe that the danger of the James and Mary is much more imaginary than real. We do not hear of ships being lost there. At all events, if there are any lost there they are so few in number that they almost negative the fear that people have of going up the Hoogly, or turning that point. I have been five times up and down myself. It never gave me the slightest anxiety or thought beyond the fact that we knew we were near the James and Mary. I passed it in March, 1857, in the "Marlborough," a ship of 1,500 tons, drawing 25 feet of water. We went over it just as easily as we went down any other part of the river. There have doubtless been ships lost there, and there is certainly this fact—that if a ship does touch on the James and Mary she may not get over. The great safety now of the navigation of the Hooghly lies in the number of powerful steam tugs which are always available. When ships had formerly to sail up, the danger was great, but now these powerful steam tugs meet ships low down in the river and bring them safely to Calcutta. The disadvantage is the delay, which has been very correctly explained by Mr. Brooks, of being obliged to anchor until the tide serves. With regard to the formation of the James and Mary, the question is one which I do not think can be decided or properly understood by an examination of the map. The locality must be inspected. The rivers which fall into the Hooghly at Hooghly point, viz., the Damoodah and the Roopnarain would then be better understood than they can be from the sketch that has been prepared, or from the description that has been given. They are both very large rivers, draining an extensive surface of country. For the whole period of our occupation of the Bengal provinces they have been the cause of the greatest anxiety, trouble, and expense to the Government. Different and ever-varying projects have been submitted for preventing the disastrous consequences of the enormous floods which come down these rivers, and which for a time it was endeavoured to control by embankment, so that the body of water which was poured into the Hooghly was very much greater than it is now. It has lately been decided by the Government to do away with the embankments through a length of about 20 miles of the Damoodah. They were found so difficult to maintain, so expensive to construct, and required so much watching, and the failures were so numerous, that at last, in 1857 and 1858, the Government decided that the embankment should be removed within the above limits, and the river is now allowed to flow over its natural banks. It would be interesting to ascertain what the effect of that arrangement has been on the James and Mary. When the Damoodah and the Roopnarain rivers were both fully embanked, and the water poured down them in the rainy seasons, what was the effect then on the James and Mary, and what has it been since the Damoodah embankments have been removed? Then, we may go back to a period far beyond that, because it is well known that the Damoodah river fell into the Hooghly, or as it was probably then called, the Bhageerutee river, about 70 miles further up, that is, at a place called Nya Serai, eight miles to the north of the town of Hooghly. What are we to suppose was the state of the river in those days? Did the James and Mary exist? or did it not exist? These are the points which are interesting in respect of the agency through which these sands are deposited, and which, I think, would guide to a considerable extent those who undertake the theory of deciding in what way the James and Mary is formed. My opinion of it is pretty much the same that Mr. Brooks and Captain Fishbourne have expressed. The waters of the Damoodah, Roopnarain, and Hooghly rivers are held up by the flood tides of the Hooghly, and during that time the Damoodah and the Roopnarain, which would otherwise pass away and carry their silt with them, are held back, and a deposit takes place. When the flood recedes, and the waters of the tributaries pass down, they keep their deep channel course, and the sand which has been deposited remains there. I believe this action is continually going on, and that the James and Mary is maintained simply by such agency. There is a part at George's point which it is exceedingly difficult to get by, and Lloyd's channel is almost entirely filled up. But it is expected, and I have no doubt it will be found to be so, that as one channel fills up another channel is opened. The Marine Department of Calcutta are engaged constantly in taking soundings, and in buoying out channels as changes render the

work necessary. I believe the Hooghly pilots are so thoroughly aware of the channels of the river that if you hand them over a ship at the floating light they would take her up to Calcutta almost with their eyes shut. They work by soundings. Therefore, fully agreeing with the lecturer as to the James and Mary being a danger in the river, I think the danger is not so great as is generally supposed, from the facilities which steam navigation has given to ships going up. It is a singular fact that in the last year the trade of the port of Calcutta has more than doubled, without, I believe, a single accident having occurred at the James and Mary sand.

Captain FISHBOURNE: I can bear testimony to the wonderful accuracy of the soundings. I have made the Hooghly at night, and I went on all night simply by the soundings, without pilots, lights, or anything else. I went on without anything more than the lead.

The CHAIRMAN: The question of docks at Calcutta is one of great importance, and if any gentleman has any remarks upon that subject we shall be glad to hear him.

General BOILEAU: The subject of docks in Calcutta is one which has engaged the attention of several parties, and which is now under the consideration of others. I have no doubt that most of the gentlemen present will be aware that there is a grand battle going on between the Hooghly and the river called the Mutlah, which is situated about 19 or 20 miles to the east of Calcutta. A railway has been formed between Calcutta and Canning Town, which, I believe, is at present not a very productive one. Canning Town is only in embryo, and the other engineering works which it is in contemplation to construct there, are scarcely yet commenced. But the Bombay people, who seem to have taken up the question lately, have got a scheme for carrying out the Canning Town project, and for erecting landing stages, and other things necessary for a large port; and if they should do this, there is every probability of that project being ere long completed. How far that will affect the question of having docks in Calcutta I am not prepared to say; but there is no doubt that those most deeply interested in the subject are taking it up *con amore*, and that in a short time we shall have docks at Calcutta, as well as a new port at Canning Town on the Mutlah river. All the other conveniences for commerce and passenger traffic, I think, railway communication affords.

Mr. BROOKS: It would be very easy to form docks at Calcutta. It has been done on a large scale in the Tyne, and done rapidly.

The CHAIRMAN: How do you propose to form the walls?

Mr. BROOKS: There the only difficult work is to get the material. The way they provide ballast for the great railways in Bengal is by burning clay. Now, the clay itself would not be sufficient; you would have to burn it in the form of bricks, but I calculate upon forming the embankment with large slopes. There is another way in which it might be done very readily indeed. There would be no pressure. The water standing outside and inside at the same level, if you could possibly place a sheet of paper between it, would make still water. That could be readily done by using screw iron piles up and down. You could do it in twelve months. Put wrought iron piles of four or five inches—put ten down every four feet apart, with three feet screws to them. Put those down twenty feet below the lowest part of the bed; then drop your plates in grooves between them, and you would readily close all up. You would have to stay it well. The only difficulty you would have would be to bear against the wind, the violent effects of the hurricanes; but you could protect it by masses of brick and stone, if you can get stone as ballast. I went into the calculation, and the entire work could be done for £300,000.

The CHAIRMAN: With the screw piles?

Mr. BROOKS: With the screw piles, putting in three-feet screws at the bottom of each pile. The piles would be above 72 feet in length. That would be a very ready way of doing it.

General BOILEAU: Would you put in single rows of piles?

Mr. BROOKS: Single rows of piles, putting in cast-iron plates—four-feet plates dropped down into the grooves with occasional stay piles.

The CHAIRMAN: What is the rise and fall there?

Mr. BROOKS: About 15 or 16 feet.

The CHAIRMAN: So that ships would have to be made fast allowing for the rise and fall of the tide.

Mr. BROOKS: Yes; all the present moorings would be undisturbed.

The CHAIRMAN: That is to say, at a certain period of the tide they could not unload.

Mr. BROOKS: They could always unload, because we have got five fathoms at low water.

The CHAIRMAN: But they would have to hoist.

Mr. BROOKS: They would have to hoist, the same as in a dock. For three months in the year, when the river is in a flooded state, it stands nearly at the same level. There is no rise and fall, in fact. The flood merely checks the downward current at high water; it does not run up. The way I have described would be a cheap way of doing the work. A dock like that in the Tyne, as per plan on the wall, constructed in the ordinary way, would have been a two million job, whereas it did not cost £200,000.

Rear-Admiral HALSTED: What is the rate of the spring tide?

Mr. BROOKS: About three miles an hour.

Admiral HALSTED: The Hooghly is a wild and capricious beast.

Mr. BROOKS: It is a wild beast; much more so than the Tyne. I have seen the tide in the Tyne running down four knots an hour; but in a dock of this kind you would not have to stem the tide—the tide would run right in. A ship could not turn at right angles into the excavated dock, as formerly proposed. It would be a very difficult operation indeed.

The CHAIRMAN: I am sure you will join me in returning our thanks to Mr. Brooks for the lucid manner in which he has put forward what he thinks is the best that should be done with the Hooghly. This question of dealing with rivers on alluvial soils is probably one of the most difficult problems the engineer has to solve, because, in the first place, he has got no foundation that he can depend upon. He cannot put down anything but what will be undermined. And we learn another lesson from what Mr. Brooks has set before us—the wonderful effect which tributaries entering into the main streams at right angles have upon the main body of the river. There we always find the most serious obstructions. I quite agree with what has fallen from Mr. Brooks that to connect the Damoodah with the Roupnarain would tend to make the place really worse than it is. The question of that proposed new cut depends entirely upon whether we can get a foundation for it. Undoubtedly that would improve the channel of the river, and entirely do away with the difficult shoal. But the question comes, if you once interfere with that point, would you not wash it all away? I should like to see the river improved, yet I do not think it can be done without sinking cylinders to an extent that would render the expense something very great.

Evening Meeting.

Monday, May 15th, 1865.

COLONEL PHILIP J. YORKE, F.R.S., Vice-President, in the Chair.

NAMES of MEMBERS who joined the Institution between the 1st and 15th of May, 1865.

LIFE.

Wason, E. S., Major, 33rd Regiment. 9*l.*

ANNUAL.

Laing, E., Ens. Middlesex Rifle Vols.
Lester, C. S., Surgeon, R.N. 1*l.*
Rogers, J. E. Varty, Lieut., 102nd Roy. Mad. Fus. 1*l.*
Aynsley, C. M., Captain, R.N. 1*l.*

THE PRESENT STATE OF THE ARTILLERY QUESTION.

By Major C. H. OWEN, R.A., Professor of Artillery, Royal Military Academy, Woolwich.

THE subject that I have to bring before you this evening presents so many difficulties, that in attempting to lecture upon it I am afraid I shall be considered rather presumptuous. As, however, one of the great objects of this Institution is to discuss such subjects, I thought that, being a member, I should not refuse, when requested by the Council and several of my own brother Officers, to read a paper on the "Present State of the Artillery Question."

There are doubtless many of my brother Officers who could give you a better and more interesting lecture than the one you will hear to-night, but none would I think take more pains than I have done to look at the various questions in an impartial spirit.

I shall endeavour in the following observations to keep to facts and principles, and to avoid mere opinions or personal remarks; but shall necessarily be compelled to review briefly the constructions and pro-

posals of several inventors. Many confused notions which unfortunately still prevail, may I think be cleared away by dividing the subject into distinct branches, and treating each of these separately. I propose then to consider—

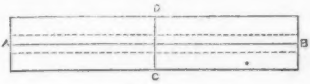
1. The materials for ordnance.
2. Methods of construction.
3. Systems of rifling.
4. Ordnance of different services.

Before proceeding, I will, however, remind you, as shortly as possible, of a few elementary principles relating to the strains exerted by the gas from the gunpowder upon the metal of a gun; for it is only by applying these, that opinions of any value can be formed respecting the relative merits of different materials and constructions.

When a charge of gunpowder is ignited in the bore of a gun the gas exerts equal pressure in every direction, and therefore, neglecting windage, the pressure on the bottom of the bore is equal to that on the base of the shot, and the pressures on the top and bottom as well as those on the sides of the bore balance each other. As the shot moves towards the muzzle, so will the space in which the gas is confined be increased, and the pressure be decreased. It is evident then that the thickness of metal may (as it always is) be safely reduced from breech to muzzle. A curve representing the pressure of the gas along the bore might be constructed on the assumption that the whole charge is converted into gas before the shot moves, but this is not the case in practice; in fact, as we know, the amount of gas generated, previously to motion being communicated to the projectile, varies according to circumstances in different guns.

The force exerted by the gas produces a double strain inside the bore—a *tangential strain*, tending to rend the metal lengthwise (through A, B, Fig. 1); and a *longitudinal strain*, which tends to fracture the gun across (through C, D,) or to drive out the breech.

FIG. 1.



The most important point to consider is the *initial strain*, or that to which the metal is subjected before the shot moves; for the gas then exerts its maximum pressure per square inch, and it is this first severe strain that usually causes the destruction of the gun. Now, in ordinary cases, the *initial* pressure exerted at the bottom of the bore by a *given charge* depends upon the amount of force necessary to set the shot in motion, for the greater this force, the longer is the time allowed for the ignition of the powder before the gas can expand.

In comparing then the strain in different guns, it is necessary to consider the resistance the projectile opposes in each case to the force of the gas, or in other words, the work the gas has to perform in putting the shot in motion. For instance, in a S. B. gun the spherical shot has merely to be rolled along the surface of the bore, and is

therefore probably set in motion when only a small portion of the powder is converted into gas. Should a cylindrical shot be fired from the same piece, there will be a considerable amount of friction between the shot and the bore, which must be overcome and cause delay. In a rifled gun additional work must be expended in giving a rotatory motion to the shot; besides which, the area of projectile presented to the force of the gas is much smaller for a given weight of shot in a rifled gun, than in a S. B. piece.* It is thus easy to account for the great proportional strain caused by a charge of powder in a rifled gun. Independently, however, of the increased strain, the grooving of the bore weakens the metal, especially if cast.

Before passing on to consider the materials for ordnance, I must also remind you, that if a gun consists of one solid mass of metal bored out, the exterior portions take but a small share of the strain. I need not dwell on this point, which has been so fully explained by Mr. Mallet, Captain Blakely, and others; and you are doubtless aware of the several proposals made and some of the methods adopted for equalizing the strains upon different portions of the metal of a piece of ordnance.

Materials for Ordnance.

The four materials generally used for ordnance are bronze, cast iron, wrought iron, and steel. In selecting a material for ordnance it must be remembered that it will not be subjected to a mere variable pressure, but that the force of the gas is percussive, resembling a blow rather than a pressure, and therefore that the tenacity of a metal is not always a criterion of its suitability for guns. The properties especially required in a metal for cannon are elasticity, toughness (tenacity combined with flexibility), and hardness; ductility will allow a greater margin of safety beyond the elastic limit, but the strain should, if possible, be confined within this limit.† It is also important that a material capable of being manufactured with certainty be chosen, and that both the material and the method of construction be not too costly.

Bronze is sufficiently tough, and can, with skill and care, be cast so as to be uniform in quality, but it is costly and too soft for the bores of rifled guns; it does not corrode like iron, and therefore requires no painting.

Cast iron possesses the necessary hardness, but is very brittle, and, even with the greatest care in casting, is of uncertain tenacity. The Americans have of late greatly improved the quality of the cast iron ordnance by the selection of the most suitable ores, and by taking means to render uniform the contraction of the different portions of the metal in cooling; nevertheless, cast iron cannot be used for rifled guns, unless they are fired with very small charges.

* In all these cases it must be remembered that although the actual differences in time elapsing between the ignition of the powder and the moving of the shot under various circumstances may be very small indeed, the ratios of the times may be high.

† According to Barlow no thickness of metal can permanently resist an internal strain greater than the tensile strength of the material.

Many attempts have been made to strengthen cast iron guns by shrinking or driving wrought iron or steel rings or tubes over the breech; the jacket thus applied, being in a state of tension, should take a fair share of the strain; and as the cast iron will be compressed, it will be in a condition favourable to resistance to strain. Numerous experiments have, however, shown that cast iron guns strengthened on the outside will not stand the great strain caused by firing heavy elongated projectiles with even moderate charges; and this result has been confirmed by the many failures of the Parrott rifled guns in America. A better plan is to place the wrought iron or steel inside the cast iron, as proposed by Major Palliser, the stronger metal being then in the position where it is the most required.

Wrought iron is an excellent material in most respects for ordnance; it is exceedingly tough, and although not so hard as cast iron or steel, and therefore less able to resist injury from the action of powder and shot in the bore of a gun, it is not liable to snap like the far more tenacious material steel, and will withstand a greater moving or percussive force. Soft iron is preferable to the harder qualities, for, as Kirkaldy remarks, "although the softness of the material has the effect of lessening the amount of the breaking strain, it has the very opposite effect as regards the working strain. This holds good for two reasons: first, the softer the iron the less liable is it to snap; and second, fine or soft iron, being more uniform in quality, can be more depended upon in practice." It is difficult to obtain large masses of wrought iron without slight flaws, caused by the cinder and impurities not thoroughly got rid of in the working of the metal; but such flaws are generally of far less consequence than cracks of equal size in cast metals, and do not, like the latter, indicate the speedy destruction of the material; flaws across the fibre of the metal are necessarily dangerous. Wrought iron, in consequence of its toughness, possesses another great advantage over cast iron or steel; when fractured it does not, like those brittle metals, fly into a number of destructive pieces, but its failure is gradual, it may be easily noticed, and so injury to the gunners may be avoided.*

Cast steel being exceedingly hard and elastic, is well adapted for the bores of guns; but although its tensile strength is very great, it is liable to snap without warning when exposed to strain suddenly exerted. However, the steels now made for ordnance, both in England and on the continent, are much softer and tougher than ordinary cast steel of good quality. The steel used for the bores of our large guns is tempered in oil, by which means it is rendered both harder and tougher.

Great difficulty is still experienced in obtaining large masses of cast steel of uniform quality, but since the successful productions of Krupp and some of our own manufacturers, it is to be hoped that this objection will be before long overcome. There remain, however, two other rather formidable objections to the employment of steel alone, viz., the

* "Out of nearly 3,000 guns made on this principle no one gun has burst explosively."—Sir W. Armstrong's Evidence, Report on Ordnance, page 134.

great cost of the metal, and its tendency, when fractured, to fly into a number of destructive pieces, which render it less suitable than wrought iron for the exterior of a gun. By hooping steel with wrought iron, the endurance of the former is doubtless much increased, and its destruction is less dangerous.*

In the above remarks on wrought iron and steel, I have not attempted an inquiry into the best methods of producing these materials; I will only remark that by the adoption of the Bessemer process of conversion, the cost of wrought iron and steel would be much reduced, but that further experiments are required before the Bessemer metals could be safely employed in the manufacture of ordnance.

Methods of Construction.

Let us now consider the methods of construction. There is little doubt but that by casting a gun in one mass much time and expense in manufacture is saved, and that many difficulties experienced in making guns in different parts are avoided. At the same time it has not yet been proved that a material of sufficient strength, combined with uniformity in quality, can be obtained for casting into heavy ordnance, which will be subjected to the strains of large charges of powder. Cast-iron is too uncertain in character, bronze is too soft and costly, and soft steel, as I before pointed out, is very expensive, it is a dangerous material when fractured, and has not yet been sufficiently tried to prove its fitness for very large guns (of over 7-inch calibre).

Another method is to form the gun out of one solid forging, and this has been strongly advocated, but has also been utterly condemned by good authorities on the subject.† For guns of very small calibre, it has been adopted with some success, but when a piece weighing many tons is required, it is now pretty generally admitted that this plan will not give the required results. Experiments have shown that the strength of a forging, like that of a casting, is less as its size increases; but besides this, some parts of a heavy forging will in most cases be more soundly worked than others, and flaws, often running in the worst direction, and which cannot sometimes be detected until too late, will occur.

Another method is to build up or construct a gun out of a number of distinct pieces, and by this plan several important advantages are obtained. 1st. The parts may be of such a size that their soundness may be depended upon. 2nd. Different materials may be used, each being placed at a part of the gun where its peculiar properties are most required. 3rd. The materials may be applied in such a manner that their particles or fibres may run in a direction most favourable for resistance to the strains to which they will be respectively subjected. There is one most important condition that must not be neglected in building up a gun, viz., to provide against the separation of the different parts, for no matter what materials are used,

* That wrought iron hoops will prevent dangerous results when the inner steel tube gives way has been shown in many of the late trials of ordnance.

† Mallet, Armstrong, Anderson, American authorities, &c.

the gun will have little endurance if the different portions are liable to be shaken asunder by the shocks of successive discharges, or by the blows of an enemy's shot. It must also be obvious that a gun constructed out of a few large heavy pieces will be less liable to destruction, from the causes just stated, than one consisting of a large number of smaller and lighter parts.

We have obtained in this country considerable experience in the manufacture of built-up guns; not, as might have been foreseen, without many disappointments and much expenditure of both time and money. We are not perhaps indebted to any individual for our present system of building up; our experience has been gradually gained, but to Sir W. Armstrong cannot, I think, be denied the credit of being mainly instrumental in combining different principles and improving details, so as to produce an efficient method of manufacture for large ordnance. He has doubtless been ably assisted, both by his own partners and by his Assistants in the Royal Gun Factory, but no one can blame him for accepting this assistance or for turning to account the many advantages of his position. In saying this, I do not mean to justify his appointment as Superintendent of the Royal Gun Factories, which it is now generally admitted was a mistake.

The essential features of the Armstrong method of construction, are:—

1st. The disposal of the fibre of the metal round the bore (by coiling), so as to resist the tangential strain, the welds running in the direction of least strain as regards their separation.

2ndly. The employment of a breech piece, to support the bottom of the bore, with the fibre running lengthwise so as to resist longitudinal strain.

3rdly. The shrinking on the different portions, so that the exterior of the gun takes a due share of the strain.*

The separation of the different parts of the guns now made is guarded against, not only by the tension of one part over another, but by means of shoulders and corresponding recesses (Figs. 2 and 3).

FIG. 2.

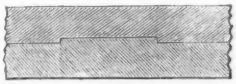


FIG. 3.

These and other details of manufacture, as the decreased diameter of the cascable in the later M.L. guns, the best form for the bottom of the bore, &c., will, I dare say, be fully explained by Mr. Anderson, who I understand will give a Lecture here on the 26th of this month. Mr. Anderson is, I believe, an advocate of a steel barrel with a closed end, and he will doubtless give good reasons for his preference.

I will here remark on the vexed question of coiled iron for the inner tube of a gun. It is often asserted that a sound coiled iron tube cannot be made, and that it is folly to attempt to produce one. I must,

* As proposed by Captain Blakely (late R.A.).

however, beg to question this statement. Large numbers of coiled iron barrels have been made, and, notwithstanding slight flaws, have shown great endurance. If flaws must occur, they are, in a well-made tube, so small, and in such a direction, that they are practically of little importance, and do not usually enlarge to a dangerous extent before the gun is worn out.* The coiled iron barrels now made of a better iron than that previously used are almost free from flaws, and those that occur are very small.† The fact is, the barrels have been abused, not only for their own imperfections, but also for the failures of the vent pieces.

Several important modifications in manufacture, which will both decrease the cost and increase the endurance of the gun, have lately been proposed in the Royal Gun Factories, by Mr. Fraser, the Manager and Assistant-Inspector of Machinery. The chief modifications are a reduction in the number of coils; the use of a cheaper iron for the outer coils; the shrinking on of the outer coils and trunnion piece together; and an improved arrangement of shoulders and recesses to prevent separation of the parts. The cost of material is thus reduced, a less quantity of metal is required, much time is saved in the manufacture, and as the parts are large and few in number, and more disposed for mutual support, the endurance will, in all probability, be increased.

Mr. Whitworth is a strong advocate of steel for all parts of a built up gun.‡ His method of building up differs from that of Sir W. Armstrong:—"The tube of the gun is made taper, being in the 5½-inch bore gun 1 inch larger in diameter at the breech end than at the muzzle end; then a series of hoops are made, which are screwed together so as to form another tube, that is put on by hydraulic pressure,§ each layer is put on a little tighter than the succeeding one." Mr. Whitworth asserts that pressure is more certain than shrinking; the latter can, however, be done with sufficient accuracy. Captain Blakely also is, I believe, a strong advocate of steel for both inner tube and outer rings, although he has also employed both cast and wrought iron for portions of some of his guns.

The method of closing the bore of a built-up gun is an important question. The inner tubes of some of the large M.L. ordnance lately constructed in the Royal Gun Factories, as well as those of some of Blakely's guns have what are termed closed ends, that is, the tube is not bored through at the bottom; the solid end of the tube in the

* Sir W. Armstrong pointed out, before a Committee of the House of Commons, the difference between the flaws in the welds of a coiled barrel and in those of a forged solid tube. He said: "In the barrel which is forged solid, the lines of the weld run longitudinally with the bore; now we not only derive greater strength from the welds lying transversely to the bore (as in a coiled tube), but we also attain greater durability, because when they run in the direction of the bore, the scour of the gas eats into them, and causes fissures in the most dangerous direction, while in the other case the scour crosses the lines of the welds, and produces very little corroding effect."—Report on Ordnance, p. 134.

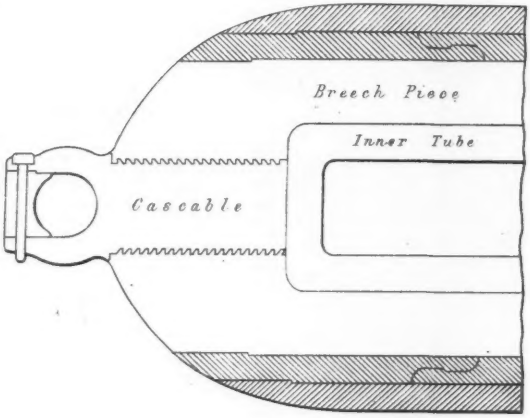
† A tube of coiled iron in a Palliser gun, after several hundred rounds, showed no sign of a flaw in a weld.

‡ The trunnion pieces of his experimental guns are of wrought iron.

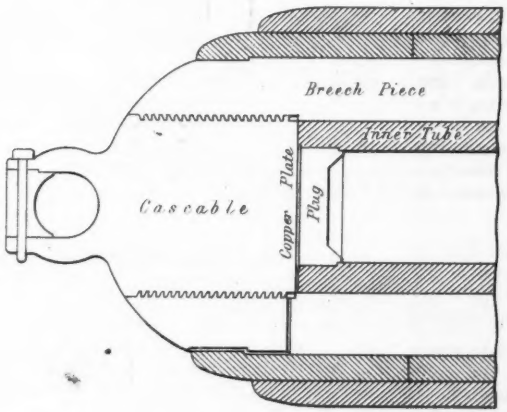
§ Mr. Whitworth's Evidence. Report on Ordnance, page 126.

Different Methods of Closing Breech of M.L. Built-up Guns.

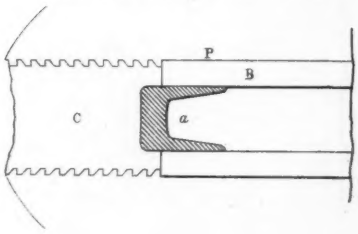
Breech of 9.2 inch Gun.



Breech of Armstrong 10.5 inch Gun.

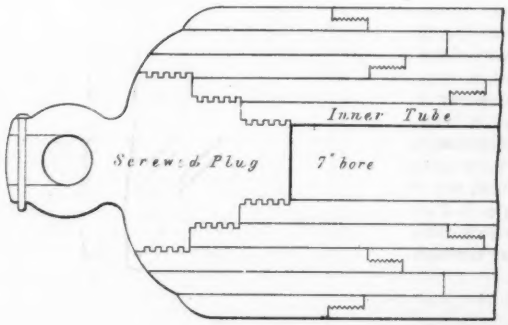


Method of Closing Bore of 64 Pr.



B. *Inner Tube or Barrel*
C. *Cascable*
P. *Breech piece*
a. *Copper Cup*

Breech of 7 inch Gun proposed by Mr. Whitworth.



service guns is supported by a cascable screwed into the breech-piece, and in some of them also by a shoulder in the breech-piece. Sir W. Armstrong, Mr. Whitworth, and Major Palliser use open tubes, and close them by a plug of wrought iron or copper. The cascable in the Whitworth guns is not, like Armstrong's, cylindrical in form, but is shaped into two or more (screwed) cylinders, their respective diameters increasing from bore to breech (see Plate xxx). In closing the bore either of a M.L. or B.L. gun, one important principle should not be neglected, viz., that as the gas exerts an equal force in every direction, the thickness of metal should be as great, or nearly so, behind as over the charge. Inattention to this principle, or its sacrifice to other considerations, is a source of weakness in many B.L. guns. One advantage of an open end is, that the metal of the inner tube is relieved to some extent from longitudinal strain.

The relative cost of large ordnance made in different ways is approximately as follows:—

	£
Cast-iron guns	21 per ton.
Armstrong built-up ditto	100 ditto.*
Krupp's steel ditto	170 ditto.
Gun-metal ditto	187 ditto.

The latter guns (bronze) are valuable for re-casting. By the adoption of the modifications proposed by Mr. Fraser, the cost of built-up ordnance will, it is said, be much reduced, viz., to £40 a ton with a coiled inner tube, and to £55 a ton with a steel tube. Mr. Whitworth's guns, like all steel guns, must be very expensive; he told the Committee on Ordnance that his 5½-inch gun, weighing 4 tons, and made of homogeneous metal (soft steel) costs £700, which is about £175 per ton.†

The following will be, I think, considered sound conclusions on this part of the subject.

A cast iron gun strengthened by hoops on the outside will fail when rifled, but by placing wrought iron or steel tubes inside, better results may be expected.

A heavy rifled gun made in one mass either of cast steel or of forged iron cannot at present be trusted.

By properly disposing and adjusting together a few pieces of moderate size, a heavy rifled gun can be produced, possessing great strength and endurance, at a moderate cost.

The best material for the bore, as also the safest way of closing the inner tube, are still open questions.

Both coiled iron and steel will probably answer for the inner tube; for the exterior portions of a gun, however, there can be no question but that wrought iron is the best, as well as the cheapest, of the two.

Various opinions are held as to the relative advantages of breech and muzzle-loading ordnance, but the latter would appear to be the

* Lately about 87*l.* † Report, page 108

best adapted to general service, as they are stronger for equal weights of metal, and simpler in construction. The advantages of loading cannon at the breech are—that a projectile of larger diameter than the bore can be used, and its axis will consequently be stable; that the gun can be loaded when run up, the gunners being therefore less exposed; that the gun can be worked in a smaller space (than a M. L. piece); the cleaning of the bore can be more readily effected, and any ignited substance left in the bore can be seen and removed; also, there is no danger of the shot not being *home*. This plan, however, is attended with the following disadvantages, viz., that the construction is more complicated than that of a muzzle-loading piece; that if the gun be of large calibre, the breech-loading apparatus, when sufficiently strong and heavy, will be unwieldy; and that with the same weight of metal, the breech-loading is a weaker and less enduring construction than the muzzle-loading.

On the other hand, a muzzle-loading gun has a simpler and stronger construction, but the gun detachment are more exposed than with a breech-loading gun, and if loaded carelessly, the shot may not be rammed *home*, in which case the metal of the gun may be fractured by the suddenly condensed gas.

Systems of Rifling.

I will now say a few words on the different systems of rifling. In what does a *system of rifling* consist? Essentially in the method of giving the rotatory motion to the projectile. This definition will not satisfy some inventors, who wish to claim a particular *twist* as a part of their *system of rifling*. It would, however, be quite as reasonable to claim a particular charge. The rotatory motion, as you all know, is given to prevent the projectile from turning over in flight; and the velocity of rotation required depends upon the form, length, and weight of the projectile, no matter what the system of rifling may be; in fact, the number of revolutions made by a shot $= \frac{\text{I. V.}}{\text{length of twist}}$, and therefore, with the same charge, the same twist must be obviously necessary.*

A twist, like a charge, may suit a particular rifled gun, but this is quite another thing. A *gaining twist* is advantageous, for, by employing it, the initial strain upon the gun is reduced, the rotatory motion not being given when the shot is set in motion, but gradually acquired as it moves down the bore. It is better to give rather more twist than is required under ordinary circumstances at the expense of a little extra strain; for should the twist be merely sufficient to impart the necessary rotatory motion with the service charge, the velocity of rotation will probably be too low with a reduced charge to keep the projectile steady in flight.†

* The I. V. is very little affected by the system of rifling.

† This was practically shown by the inaccurate practice of the 600-pounder, when fired with a small charge.

The diameter of the bore has also been often mixed up with the system of rifling, with which it can have nothing whatever to do. As the diameter is decreased, so will an elongated projectile oppose a less surface (in proportion to its weight) to the resistance of the air, or of that of the substance fired at; but, on the other hand, it will expose a less area to the force of the gas, and will therefore have a lower initial velocity; it will have less capacity as a shell; its cartridge must be elongated, thereby throwing the strain forward, the amount of powder that can be usefully employed will be less, and if the length of the bore be not increased, the expansion of the gas will be more limited. This question has been discussed in this room, and should be now thoroughly understood. In the table below the loss of initial velocity by decrease in the size of the bore is clearly shown:—

Ordnance.	Charge.	Projectile.		Initial velocity.
		Weight.	Diameter.	
	lbs.	lbs.	inch.	
Britten's (32-pr. rifled)....	5	50·36	6·24	1209
Armstrong's 40-pr.....	..	41·25	4·75	1197
„ 3 grooved shunt	9	68·40	6·4	1283
Whitworth's 70-pr.....	..	68·56	$\left\{\begin{matrix}5·5\\5\end{matrix}\right\}$	1132
Armstrong's 70-pr.....	10	74·60	6·4	1271
Whitworth's 70-pr.....	..	68·56	$\left\{\begin{matrix}5·5\\5\end{matrix}\right\}$	1199

Mr. Whitworth and his admirers have constantly asserted that his small-bore gives a flatter trajectory than the larger bores chosen by Armstrong, Britten, and others. This is, however, not the case under all circumstances, and arose partly from the fact of the Whitworth guns first tried, being fired with charges of $\frac{1}{6}$ of the weight of the projectile, whereas the greater number of other rifled guns used charges of only $\frac{1}{8}$ or $\frac{1}{10}$. Mr. Whitworth is quite right to use as large a charge as he can, but this must be taken into account in drawing comparisons. In practice from two rifled guns of different calibres, but firing projectiles of the same weight with equal charges, the large bore will give a lower trajectory for a short range than the small bore, but at long ranges the small bore will give the lower trajectory. For the larger bore will give the higher I. V., and therefore up to a certain range the lower trajectory; but as the projectile with the smaller diameter is less retarded, its trajectory will gradually become lower, as compared with the other, until beyond a certain range the smaller bore will give the lower trajectory. Small bores have found little favour on the continent, and it is for the authorities to demand either a large or a small bore, as circumstances may require.

The following conditions are requisite in any rifled gun to ensure accuracy of fire:—a rotatory motion must be given to the projectile

round an axis parallel to, or coincident with, that of the bore ; the axis of the shot must be stable on leaving the bore ; and the velocity of rotation imparted to the projectile must be sufficient to counteract the pressure of the air tending to turn the shot over or render it unsteady in flight.

Great numbers of rifled guns with projectiles to correspond have been proposed, but most of the *systems* of rifling that have been adopted by any service, or tried on the practice-ground, may be divided into the following classes :—

(1) Muzzle or breech-loading guns having projectiles of iron fitting the peculiar form of the bore mechanically.

(2) Muzzle-loading guns, with projectiles having soft metal studs, or ribs to fit the grooves.

(3) Muzzle-loading guns, with projectiles having a soft metal envelope, coating, or cup, which is expanded by the gas in the bore.

(4) Breech-loading guns, with projectiles having a soft metal coating larger in diameter than the bore, but which is compressed by the gas to the form of the bore.

I shall only give types of each class, for there will be no occasion to explain the different systems, which have been so fully described by Captains Scott and Fishbourne.

The Whitworth and Lancaster systems may be taken as examples of the 1st Class.* The great advantage shared by both is, that the projectile is made of only one metal; but as this must be iron, a steel bore is indispensable. Unless both bore and projectile are turned with great accuracy, and cleared from rust or dirt, the projectile may jam in loading—a very serious objection, for in the heat of action the gun might be fired when the shot was not home, and thus be burst. Mr. Whitworth has very ingeniously modified the hexagonal form, so as to facilitate the loading, and if enough windage be allowed, difficulty in loading will not probably be experienced; as, however, the windage is increased, the fire will be less accurate, and the bore will suffer more wear. The hexagonal form is unfavourable as regards capacity of shell, and as the projectile is made of hard metal, the *gaining twist* cannot be employed either in a Lancaster or Whitworth gun. In the Lancaster there is a much greater tendency to jam than in the Whitworth system.

The French, shunt, and Scott's systems belong to the 2nd Class. In all, the shot is centred so as to ensure stability of axis, there is no difficulty of loading, and, as the driving sides of the studs or ribs can be made of soft metal, the wear of the grooves is much reduced, so that either iron or steel may be used for the bore. By placing on the shot smaller studs in front than behind, a gaining twist may be employed.

Bashley Britten's system is a fair example of the 3rd Class; it possesses several important advantages, viz., easy loading, accuracy of fire, and but little wear of the grooves; but the projectiles will not bear large charges, the expanding envelope giving way. Parrott's and Blakely's systems are nearly similar in principle.

* Lancaster now has a few copper steadying studs to facilitate loading.

The Armstrong and Prussian B. L. systems belong to the 4th Class. With these the bore can be readily cleaned, the loading can be easily performed, in the smaller natures of guns at least, and the soft coating does not injure the bore. The chief disadvantage is the great initial strain due to the necessity of the compression of the lead coating.

The system of rifling is not, after all, of such very great importance; good results, as regards accuracy of fire, may, doubtless, be obtained with most of them, if both guns and projectiles are manufactured with equal skill and care.

Ordnance of different Services.

I will now endeavour to compare British with foreign ordnance, and I think I shall be able to show that our condition is not quite so hopeless as has been represented, but rather the reverse. I shall not allude to the S. B. cast-iron or bronze ordnance, with the capabilities of which we are all well acquainted. I will take the different natures of guns in the following order:—

Field guns (including position pieces).
Siege and garrison guns.
Naval and coast battery guns.

It is now pretty generally acknowledged that rifled ordnance should be used in preference to S. B. guns for land service. The English, Americans, French, Prussians, and other leading powers, are supplied with rifled guns both for field and siege service; a proportion of S. B. pieces may be retained, but chiefly with a view to economy. In the late American campaigns considerable numbers of S. B. guns were employed by both sides, but this may be easily accounted for; the country is so densely wooded that case-shot ranges are frequently the only ones practicable, and, no doubt, both sides were obliged to use any guns that they could procure.

You are all aware that the advantages gained by substituting rifled for S. B. guns, are

Increased accuracy of fire.
Destructive effects at greater ranges.
Capacity of shell.

The two latter being due to the elongated forms of the projectiles fired from rifled guns.

By placing the weights of projectiles, the proportional charges, and the bursting charges of the shells, of different field guns in a table, the relative values of the latter as weapons may be compared.

RIFLED FIELD GUNS.

	Nature of Gun.	Weight of Gun.	Charge.	Projectiles.				
				Shrapnel or Segment.		Common Shell.		
						Weight.	Burster.	
		Cwt.	lbs.	lbs.	oz.	lbs. oz.	lbs. oz.	
British.	20-pr.	16	$\frac{1}{8}$	19	10	20 8	1 0	
	12-pr.	8	,,	10	8			
	9-pr.	6	,,	8	5			
French.	Cannon de 12	12	$\frac{1}{10}$			25 4	1 1	
	do. 4	$6\frac{1}{2}$	,,	11	7	8 12	0 7	
American.	20-pr.	$15\frac{1}{2}$	$\frac{1}{10}$	19	8	18 12		The weights in the column of shrapnel for American guns are those of solid shot.
	10-pr.	8	,,	10	8	9 12		
	3-in.	$7\frac{1}{2}$	,,	10	0	10 0		

The Prussian 12-pr. steel rifled gun weighs rather more than 7 cwt., the charge is $\frac{1}{10}$, and the projectiles weigh about 13 lbs.

For ready comparison I have given the weights of guns in cwts., and the weights of the charges in terms of the weights of their respective projectiles. I have purposely omitted mountain artillery, as, in a short lecture, my remarks must be confined to the most important questions.

The table shows that the projectiles of the different guns differ little in power, the French having a slight advantage; the British, however, are fired with the highest velocities.

		Velocity in feet.
British.	20-pr. common shells	1114 per second.
	12-pr. segment.....	1218 do.
	9-pr. do.	1036 do.
French.	Cannon de 12 common shells	1006
	do. 4 do.	1066

The French employ three kinds of projectile, and all experience shows that one projectile will not answer three distinct purposes. Common shells are often required under circumstances where segment shells would be useless; and a case-shot which depends for its action upon the preparation of a fuze is very objectionable; simple case-shot and common shells will probably be introduced into the field-service batteries. In actual warfare our Officers have generally kept a number of segment shells with their fuzes prepared for case firing.

As regards precision of fire, I have little hesitation in saying that the practice of our B. L. Armstrong guns is quite as accurate as can be required for any service, and I believe more so than that of most of the foreign guns. I will give you an instance. In the Aide-Mémoire de Campagne, of 1864, the mean errors, both in range and direction of projectiles fired from the canon de 12, are so eccentric that nothing can be made of them: at 1,300 metres the error in range is only about one-sixth of what it is at 400 metres, and at 2,050 metres the error in direction is less than it is at 700 metres. The canon de 4 appears to be a more accurate gun; the mean errors in range at 1,000 and 1,800 metres are 22 and 27 metres respectively; those in direction and at the same ranges, 1·2 and 2·5 metres. With our B. L. rifled guns the mean errors in range at 1,000 and 2,000 yards are 19 and 21 yards respectively, and in direction ·8 and 2·1 yards respectively.

The Prussians, like ourselves, employ B. L. guns for field service, the French, Americans, and others, M. L. guns. In the Armstrong B. L. (screw) system, strength has been to some extent sacrificed to easy loading, but notwithstanding the abuse poured down upon both the method of closing the bore and the whole construction of our B. L. field guns, they are perfectly safe and can be readily served; the vent-piece* lasts but a short time compared to the rest of the gun, but should one fail it can be easily replaced by another, and the present form prevents dangerous results.

The Prussian field guns are of Krupp's steel; the French and some other nations have converted their S. B. bronze guns into rifled pieces, thus utilising their old *matériel*, but not obtaining ordnance that will wear like wrought iron or steel guns. The American 3-inch gun is a solid forging, and as it is so small, the metal is probably sound.

Let us now compare the siege and garrison guns.

* In consequence of its support by the breech-screw being only partial, and the vent being bored through it.

RIFLED SIEGE OR GARRISON ORDNANCE.

	Nature of Gun.	Weight of Gun.	Charge.	Projectiles. Shot.	Shrapnel or Segment.	Common Shell. Weight.	Common Shell. Burster.	
		Cwt.	lbs.	lbs. ozs.	lbs. ozs.	lbs. ozs.	lbs. ozs.	
British.	B. L. 7-in. (heavy) ..	81	$\frac{1}{9}$	90 0	98 0	98 0	8 0	Charge will probably be reduced
	do. (light)	73	$\frac{1}{10}$	90 0	98 0	98 0	8 0	
	M. L. 64-pr.	65	$\frac{1}{8}$	64 0	62 10	60 0	4 8	
	B. L. do. (wedge) ..	$61\frac{3}{4}$	„	64 0	61 14	60 0	4 4	
	B. L. 40-pr.	35 / $32\frac{1}{2}$	„	41 3	39 0	38 5	2 8	
American.	100-pr.	$86\frac{1}{2}$	$\frac{1}{7}$ to $\frac{1}{10}$	70 0 / 100 0	..	100 0	..	Burster about 8 lbs.
	30-pr.	$37\frac{1}{2}$	$\frac{1}{10}$	30 0	..	25 0	..	Burster rather over 1 lb.
	French..	56	$\frac{1}{9}$ to $\frac{1}{13}$	60 0 / 100 0	..	..	..	
	Spanish	62	$\frac{1}{9}$	61 0	..	..	..	
	Prussian	$53\frac{1}{2}$	$\frac{1}{10}$	..	..	57 0	2 0	

As our guns are of wrought iron, but those of the Americans, French, and Spaniards are merely hooped cast iron guns,* there can be but little question as to which would prove the safer and more enduring pieces. The Prussian gun in the table is simply a cast-iron gun, but they have also some steel pieces. The formidable effects produced by the shells of the 40-pounder and 7-inch guns (owing to their large bursting charges) have been amply shown in our own experiments. The 7-inch guns were intended as naval pieces, and their fire would be most formidable against wooden ships, for which purpose they were constructed; they are mere shell guns, and undoubtedly the worst Sir W. Armstrong made; but it must be remembered that they were introduced without proper experiments, when there was a great pressure for rifled guns, and when it was erroneously considered that guns should be made as light as possible. The B. L. screw system cannot be applied with advantage to guns of such a size, unless the charges are very small; with large charges, if the vent-piece is sufficiently thick, it is too heavy to handle conveniently. But the 64-pounder and the 40-pounder are excellent guns.

We now come to the ordnance required for ships of war and coast batteries, which must be constructed to bear very large charges of powder and heavy projectiles, so that their fire may prove destructive to iron-plated vessels; an object some people seem to imagine the only legitimate one left to artillery of the present day.

It will be sufficient for our purpose to compare the heavy British ordnance with those of the Americans, for other nations have done little or nothing in the manufacture of guns throwing projectiles over 100 lbs. in weight. We sometimes hear mysterious rumours of monster guns supplied to foreign governments, but as they are also said to have been made in this country, we need not be alarmed. In fact, as we publish the results of our experiments, we cannot be surprised if other nations wait, perhaps wisely, until a certain amount of success has been obtained in the manufacture of large guns, and while thus saving their money, they will be enabled to start at once with good materials and tried constructions. Of this, however, we may be certain, that whatever power possesses the best guns at the commencement of a war will have a great advantage over others not so well provided; although such pieces cannot for long be confined to any one particular service.

In the table I have only given the American S.B. ordnance. The United States have also two large rifled guns.†

Gun.		Projectile.		Charge.
8 inch	.....	175 lbs.	.....	16 lbs.
10-inch	.....	250 „	.....	25 „

But as they are hooped cast-iron ordnance, they failed, as might have been expected; and after six had burst in the Federal fleet, while bombarding Fort Fisher, and 44 men were killed, they were condemned in the strongest terms as unsafe by the Admiral.

* American, hooped with wrought iron; French and Spanish with steel.

† They have also a few Blakely and other rifled guns, but the Parrott rifled guns are alone recognised in their latest official tables.

BRITISH M.L. BUILT-UP ORDNANCE.

	Gun.			Projectile.	
	Nature.	Weight.	Charge.	Weight.	Burster.
		Tons.	lbs.	lbs.	lbs.
Rifled.	13·3″ (600-pr.)	23	70	Steel shot .. 603 „ shell .. 585	24
				Cast iron do .. 554	42½
	10·5″ 300-pr.	12	35	Steel shot .. 301 „ shell .. 297	15
	9·2″	12	44	Steel shot .. 221 „ shell .. 206	11
				Cast iron do. .. 202	15¼
	7·″ L.S.	7	25	Steel shot .. 100 Cast iron do. .. 100	
				Cast iron shell .. 93	7½
	7·″ N.S.	6½	25	Do.	
	64-pr.	3¼	8	Cast iron shot 63½ „ shell 60	4½
S. B.	150-pr.	12	40 35 20	Steel shot .. 168 Cast iron do. .. 150 „ shell .. 104	6½
	100-pr.	6	25 20 12	Steel shot .. Cast iron do. .. 94 „ shell .. 66	

S. B. CAST IRON AMERICAN ORDNANCE.

Gun.	Weight of Gun.	Charge.		Weight of Shot.	Weight of Shell.	Bursting charge of Shell.
		Service.	Minimum.			
	Tons.	lbs.	lbs.	lbs.	lbs.	lbs.
20-in. L.S.	51·42	100	..	1,000		
do. N.S.	44·64	100	..	1,000		
15-in. L.S.	21·91	50	..	440	330	17
do. N.S.	18·75	35	60	400		
13-in. L.S.	14·61	30	..	300	224	7
do. N.S.	16·07	40	..	280	224	
11-in. N.S.	7·14	15	20	170	130	
10-in. L.S.	6·72	15 shell 18 shot	..	127½	100	3
do. N.S.	5·35	12½	16	125	100	
do. N.S. (or 125-pr)	7·36	40	..	125	100	

All cast hollow, except the 10-in. of 5·35 tons.
All shell guns except 10-in. 125-pr.
20-in. gun only, at present, experimental.
Solid shot are only to be fired from the 15-in. N.S. gun at iron clad vessels, and then with 50 lbs.; 20 rounds may, however, be fired with 60 lbs.

The S.B. guns are formidable weapons, although they are merely cast-iron shell guns. The 20-inch gun is at present only an experimental piece; and I think we may safely conclude that for some time to come there will be very few of them, and the few that may be made will be very cautiously used. The bursting of the 15 or 13-inch gun would probably completely paralyze a ship's crew, and destroy all confidence in these pieces. Our guns being made of wrought-iron will not, on failure, break up like cast-iron or steel ordnance; and from their accuracy of fire, the capacity of their shells, and the power these latter have of maintaining a comparatively high velocity (in consequence of their elongated form), the British are in all probability greatly superior as weapons to the American guns.

One of the most important questions at the present time is this, are monster guns required? Opinions are divided; but let us turn to facts, and see what has been done. I have endeavoured, in the following table, to arrange some of the leading facts in order, so as to give an idea (necessarily a rough one) of the projectiles and charges necessary to actually penetrate certain structures at different ranges. I have not chosen the targets in preference to any others, but simply believing that they represent the average resistance offered by sea-going vessels, and also for convenience of comparison.

TARGET PENETRATED BY STEEL ELONGATED PROJECTILES.

Range.	Weight of Gun.	Projectile.		Charge.	Target.
		Nature.	Diameter.		
yds.	cwt.	lbs.	in.	lbs.	
200	8	12 shot	3	1¼	2½″ iron plate.
„	„	12 shell	„	„	„ and 12″ wood backing.
„	81	110 shot	7	12	5½″ iron plate.
„	134	104 „	„	25	Warrior.
600	148	130 „	6·4	25	„
800	tons	130 „	„	27	„
1500*	12	221 „	9·2	44	Small plate.‡
„ †	„	301 „	10·5	45	„
2000	22	610 shell	13	70	Warrior.

It appears then, from what has been already accomplished, that there is at present no occasion to employ monster ordnance for the destruction of ordinary plated vessels. The guns we are now making, which will throw projectiles of 200 or 300lbs. weight, with charges of 45lbs., are, if properly used, which no doubt they will be, quite sufficient for the purpose. Further than this, however, it is probable that few iron plated sea-going vessels (now afloat) could withstand the fire

* Ascertained for this range by using a 30 lb. charge at 200 yards.
† do. do. 35 lb. do.
‡ 5½ inches of iron and 27″ of wood; the wood and iron not disposed in such an advantageous manner for resistance as in the "Warrior" target.

of our rifled 7″ guns of 130 cwt., fired with 25lbs. charges, at 800 or even 1,000 yards range;* for we must remember that, in actual warfare, vessels are constantly subjected to a continuous fire, and not merely to a few blows delivered at certain intervals of time; and, that a structure may thus be kept in a constant state of vibration by the repeated impacts of shot, and will offer less resistance than when time is allowed, between the rounds, for the metal of the armour to resume its former condition of repose. We should also remember that the few plates upon which experiments are usually made are in all probability of sounder construction, than those produced in quantities for the plating of several vessels; also, that when a ship has been for some time at sea, and may in addition have been in action, the armour (bolt plates and fastenings) will have been subjected to many shocks and strains, and will, therefore, have been considerably weakened.

I may here remark that Mr. Whitworth deserves great credit for showing that more might be accomplished against iron plates, by employing rifled guns of moderate weight and hard projectiles, than by firing at them with a rude monster like the Horsfall gun, with the much-vaunted round ball; also for proving that iron plates could be pierced by shells, at that time considered next to an impossibility. It is now probable that we shall not be compelled to use steel for our projectiles; the *chilled* iron shot proposed by Major Palliser giving promise of success.

For the destruction of floating batteries, monster guns would certainly be required, but may not be procurable, as such batteries could be made practically invulnerable. For naval actions S. B. guns may be necessary; but it is easy to choose a system of rifling which admits of both spherical and elongated projectiles being fired from the same gun. I will, however, venture to say that rifled guns that will bear a charge of $\frac{1}{3}$† will answer every purpose.

I might have been expected to allude to the late Armstrong and Whitworth experiments, but I have purposely avoided doing so, for I never could see that any object would be gained by them, except the probable satisfaction (or rather increased dissatisfaction) of two rival manufacturing firms and their respective adherents. Whatever the report may be, I cannot believe it will satisfy the Officers of Her Majesty's service.

As far as my branch of the Service is concerned (for I will not presume to say what course should be taken with naval armaments), the Government has ample means of obtaining the best information and advice on a purely artillery question (the respective merits of two guns), from a regularly constituted Committee, a School of Gunnery, and a Director-General of Ordnance, besides many Artillery Officers of

* The result of a recent experiment shows "that a structure such as the 'Warrior' can be penetrated at 200 yards range with elongated shot and shot cast in chill, when the form of the head of the latter is elliptical, fired from a 7″ rifled gun with $\frac{1}{4}$ charges;" and the report adds, "but it is probable that had the 7″ steel shot been elliptical headed, instead of hemispherical headed, penetration would also be effected at the longer range" (1200 yards).

† $\frac{1}{4}$ has lately been fired with success.

high rank and great experience, and who hold responsible positions in or near London. Then why ignore these, and appoint a mixed committee, many of the members of which can know nothing whatever concerning the requirements of the service. As for the Artillery and Naval Officers on it, a better selection could not probably have been made; and I would not say a word against any of the other members, who are all able men, and have no doubt done their best to obtain true results. But the decision upon a mere artillery question should not be left to a mixed committee.

Purely scientific experiments* are often better left to committees composed of Officers and well known men of science, but these should not be mixed up in any way with trials of guns, carriages, or other *matériel.*

John Bull must learn patience, and not expect to re-model his artillery in a year or two; and he should also turn a deaf ear to the loud and positive declamations of amateurs, and trust all questions of armament to those who are educated for and spend their lives in the service. Those who propose valuable inventions, and still more those who spend time, thought, and money in carrying them out, deserve our gratitude, and should be amply rewarded by Government, but they should not therefore be constituted judges of other inventions, or, unless Officers of experience, be taken as authorities on military or naval questions.

The CHAIRMAN: I am sure the meeting will support me in returning our best thanks to Major Owen for his very excellent summary of a difficult and complicated subject. I dare say there are many gentlemen present who take an interest in the subject, and now is the time for them to make any remarks.

Captain FISHBOURNE, R.N., C.B.: I am sure that Major Owen deserves credit for the measure of impartiality which he has given to the subject. But as a naval man, and representing those who have contended for the smooth bore, I am not satisfied with the curt way in which he has dismissed its merits. And while I would admit that Major Owen is correct in saying that you can get accuracy with any description of rifling, if you will only invest the same amount of mechanical skill in rifling the gun in each case, yet there are other questions which make a very material difference as to what description of rifling is best. As respects naval matters, and the gun which has obtained the latest favour, as we gather from the papers, it appears to me that there is a very decided objection to it for naval purposes. I mean what is called the French gun with large studs. Why it should be adopted without almost any experiments, I am at a loss to conceive; inasmuch as the failures, with the enormous expenditure that has been fruitlessly incurred, have taken place, because of the insufficient experiments that have been made. Now, we are going to jump into the adoption of another system without any sufficient experiments whatever. It must be very patent to anybody who considers the matter, that in firing a shot with studs at an iron plate, although it may be equally accurate with another shot of a different description, those studs must be sheared off before the shot can penetrate through into the ship—this is a very serious objection. There is another objection to it, which is a very serious one. Take, for instance, one of its shells, the holes for the studs penetrate half way through the metal, consequently reducing the strength of it very materially. Now, a most important advantage is that of having the power of penetrating iron plates with shell. But if the shells are weakened to that degree, to get equal strength with a shell that

* To ascertain the laws of resistance of the air, or those of different materials to the impact of projectiles, &c., or the suitability of any substance (as gun-cotton) to military purposes.

is not cut away, you are obliged to reduce the size of the shell, and with that the powder capacity. Here is a section of a shell of this kind. The strength of the side of the shell is only equal to its weakest part; whereas if you have no studs, but have a rib of the description of that on Captain Scott's shells, the side of the shell, instead of being weakened, is strengthened, and there is really no obstruction to the entrance of the shell into the iron plate, inasmuch as this rib is but a knife edge; and so far tends to cut in rather than to offer any retardation. Then, with respect to the general question of the smooth bore, or rifle gun, the whole question of tension is utterly ignored. And yet that is the very difficulty that we have always had to contend with—to get guns strong enough to bear large charges, as Major Owen justly says; for a naval gun must be a gun that will stand large charges; and just in proportion as you have a gun that will stand large charges, in that proportion, you do not want monster guns. Take, for instance, some of those experiments that Major Owen has been referring to; the 168 lb. shot fired out of a 10½-inch gun, as compared with the 300 lb. shot fired out of the same gun. The *effect* was much about the same. The difference of charge of powder was only 5 lb.; one was fired with 45 lb. of powder, the other with 50 lb., yet if you multiply 45 by 300, and 50 by 168, you get the relative strain brought on the gun under different conditions, irrespective of the strain, the result of the retardation from the rifling. Major Owen says that is not much. But I cannot understand the argument, that the retention of the shot occasions development of power, unless there is a development of strain also. We know very well that there is a result arising out of it, hence these guns do not stand. Here is a section of the Woolwich gun, with the arrangement of large grooves that are necessary for these large studs. This is one of the shot. You see the studs; you see how much the bore of the gun is cut out. Take the Scott groove and compare it with this. The depth of the groove in this is nearly double that of Scott's, and the width of it is considerably more than double. You can see how much of the gun is taken out, and how much the inner cylinder of the gun is injured by it. Then, again, I must take exception to the view which Major Owen has put forward as to the advantage to be gained by its gaining twist. I believe it is a great mistake. I have no hesitation in saying, that when you come to use large charges, which are—I will not say indispensable, but which are economical for naval purposes, (for in proportion as you have these large charges you can have smaller guns, and a greater number of them, and more effective guns into the bargain), I say, if you use the large charges that may be used with a description of rifling, and such a description of shell as those of Captain Scott's gun will admit of, then, as a necessary consequence of that gaining twist, the Woolwich gun will not stand; the effect will be something like a cart moving along a road at a considerable velocity, on coming to a stone suddenly, it jumps up. You allow a shot to acquire an enormous velocity, then you shunt it. It is like shunting a railway train going at full speed—that which no one is mad enough to do—as the trains always slacken their speed. That is just what takes place here, from the suddenness of the curve; the shot starts straight, but when it has got an enormous velocity, its course is changed by this curve. The necessary consequence is, that only some of the studs have a bearing; they do not all bear along fairly; this produces an oscillation, and it is not until the shot has proceeded a considerable distance that it loses the oscillation which is acquired by the sudden jump given to it by the alteration of the curve. I would take this opportunity of saying that I contend that in no one of the experiments—(I will challenge any one to produce a single experiment that has been duly fair to the spherical shot as compared with the rifled)—has there been a fair comparison; and I contend, with such a large amount of money as has been expended on such experiments, that at this day we should not be left without a fair, distinct, and satisfactory experiment—I mean such an experiment as would satisfy, or which at least could not be taken to pieces by those who are contending for the use and value of the smooth bore; more particularly as so large an economy is involved in the question. I say that the tension which has been the great difficulty that we have had to contend with, has been altogether overlooked—the tension occasioned by the round ball is exceedingly small, and the charges have never been increased proportionately. The answer is that smooth bores cannot burn so much powder. But has the powder been adapted

to the conditions of the smooth bore as it has been adapted to the conditions of the rifled bore? Has the amount of powder it would burn been tried? No. When the rifled-bore guns were bursting, what was done? A slow-burning powder was invented, but has a fast-burning powder been tried for the conditions of the smooth-bore round ball? No, it has not. The same powder has been used, when the conditions are altogether different, and require altogether different powders. While we are living in a scientific age, many of the experiments have been of the most unscientific character. This ought not so to be. As a Naval Officer, I cannot agree altogether with Major Owen, in saying that we are not to go outside the Services for advances on these subjects. Both in my own Service and in the Army, our advances have been altogether from the outside. You may remember the controversy that there was between Sir Charles Douglas and Mr. Clark, respecting Naval Tactics. A great deal of good is to be got from the outside. I think the tendency of Naval and Military men, and, indeed, of all professional men, is to get into grooves; but in this case we have got into the wrong groove, and seem determined to stick there, instead of trying to get out of it.

Commander SCOTT, R.N.: I would make one or two remarks in reference to the subject. With respect to the Horsfall gun, Major Owen omitted to say that the shot struck the ground 800 yards short before it struck the target on ricochet, and that although it did strike the ground it went nearly through the target. Then, again, the Horsfall shot was not of steel. If it had been of steel, who could doubt that it would have gone through; but although the shot was of cast iron, had it not ploughed up the ground first, it would have gone through the target. The Whitworth cast iron shot produced no effect on the target. The reason that naval men do contend for the round ball firing is just on account of what Major Owen has said—that you may not get the rifled shot home if you are in a hurry. I think when you are yard-arm to yard-arm with an enemy you would like to fire away as fast as possible. We know that unless your ship can keep up a continuous fire you are likely to be overpowered. You may have a very valuable rifled gun indeed. It may be capable of hitting the smallest object at three and a half miles; still, what you would really want to do where you are yard-arm to yard-arm is to fire away and keep down your enemy's fire; therefore, naval men think it very undesirable to give up the round ball. We do not wish to throw away the advantages of the rifle, especially as we can superadd to the advantages of the rifle the round ball firing. Captain Fishbourne has pointed out the difference between the groove of my seven-inch competitive gun and the French groove. The French groove is rather more than twice as deep as mine, and taking things as they are at the present time, the initial velocity of the round ball fired from my gun is 2,162 feet per second, which is, I believe, the highest velocity ever obtained in round-ball firing. I would remark, with reference to the late competition of seven-inch guns, that there has been no quick firing at Shoeburyness with them. One can only conclude, therefore, that these guns cannot stand their charge of 25 lbs. of powder in quick firing. I do not believe they will stand this charge with elongated shot; and if they will not stand 25 lb. of powder in quick firing when yard-arm to yard-arm, we have certainly been very much mistaken as to the effect which these guns were expected to produce. We know, however, the guns will stand the highest charges you can put into them with the round ball. Another thing we want a rifled gun for, is shell firing. In the competition firing at Shoeburyness there has been no shell firing. Whatever may be the case against plates, we shall, against wooden ships, want to fire shells with fuses in them. If you do not put in fuses we know that against the wooden ship's side there will be no explosion. Well, this kind of firing has not taken place at all. I more particularly mention it because in the gaining twist of the French gun the shell lies in the bottom of the bore. It goes along the bottom of the bore until it meets a part of the groove which lies sufficiently across the bore to throw the shell upwards. When it meets that part and is thrown upwards, there is a jar against the upper side of the gun. The effect of that jar may be seen in one of the guns rifled on that plan which was cut open at the arsenal at Woolwich. I have no doubt myself that we should, when using shells in firing from such guns, have constant premature explosions. Major Owen has spoken of the chilled iron being

valuable. I believe myself, as the chill is on the outside of the iron, that it merely makes the iron very hard there, but it does not penetrate into the inner part of the iron. The shot or shell in this state is very brittle, and not in a proper condition, especially for a shell at all. At sea it is of immense importance to be able to produce the greatest possible effect. When we can get the better projectile we shall certainly not use the worse; therefore, any Commander having steel projectiles which he can fill with powder, and which will go through into a ship and burst there, would never think of using chilled projectiles, which would break up at the moment of impact, for he would then lose entirely the destructive effect of shells penetrating and bursting between decks, which will be so fatal in actions on board ship. I would remark with respect to another point that the seven-inch breech-loading gun with the powder charge and weight of projectiles given in Major Owen's table does not really represent the state of artillery at the present time, for the size of the shot and shell is being reduced, and the latter will not have capacity for an 8 lb. bursting charge; and, therefore, the seven-inch gun is by no means the formidable gun that is there represented. With respect to the Parrott guns, they answered very well when fired slowly, but they broke down in bombardment directly they commenced firing rapidly. Now, as we have not fired any of our large guns rapidly, we do not know what the effect will be upon them. I think it important to know what these guns will do in rapid firing, and what the French gun with the gaining twist will do. It should be tried in rapid firing against the other competitive gun, which has a longer bearing. There is a long continuous bearing in one case, and only a line of bearing in the other, until the projectile gets near the muzzle. Until then there is but one stud touching, and it merely bears on its edge; and as the projectile is continually advancing along an increasing curve, the stud is continually bearing upon different lines of its surface, therefore the wearing action from bearing upon so small a surface must be very much greater than if you had a long continuous surface. Another point of importance is that if you have that straight line of rifling at the breech of the French gun, how are you to keep your shot home in the rolling motion of a ship? The shot will certainly slip away from the charge. Where the rifle twist is across the bore of the gun at the breech, the shot will roll against the bearing side, and then back to the loading side of the groove, and will not start; but where the groove is straight with the axis of the gun, the shot in bad weather is liable to roll right out, unless there is a wad in front. We do not fully know what the effect of a wad will be, but we know it will add considerably to the strain upon the gun. I would say also, with respect to the Parrott guns, Major Owen has been comparing the Parrott guns made during the war with our guns brought up to the present time. That is, I think, a wrong sort of comparison. You should compare them instead with what we intended to use at the time the Parrott guns were made. At that time there were a number of guns cast for our own navy. They were cast in a peculiar way. Most of those present will remember them, and they were intended to be strengthened with cast iron hoops outside. There were a great number of these castings ordered, but 300 of them only supplied, and 100 of them hooped, before it was found that they burst after a few rounds. These were the guns we intended to have rifled and placed in our ships in 1862, so that what occurred in the American service would, had our ships been thus armed, have occurred in our own, and these are the guns with which, I think, the Parrott guns ought to be compared.

The CHAIRMAN: The title of Major Owen's paper is the present state of the ordnance question.

Major OWEN: I did not go back at all.

Captain SCOTT: I am not objecting to facts in Major Owen's statements, but the comparison was made with the American guns produced about that time, and the manufacture of which there was a necessity to go on with.

The CHAIRMAN: It is the actual gun we are dealing with.

Captain SCOTT: The cast-iron Parrott is the actual gun of America, because there has been no opportunity for experiments, so I take our rifled cast iron guns, which were the guns making at the time when the Parrott guns were commenced.

Major OWEN: I have not touched on the history of the subject at all. I take the guns as they are now in the service.

Captain SCOTT: But you compared them with the American guns. Therefore, I think it is fair, on the other hand, to show the position of the American ordnance at that time.

Brigadier-General LEFROY, R.A., F.R.S.: I have heard a great many things from time to time in this theatre which have astonished me, but I can safely say I never heard here anything which has so astonished me as the statement that has just fallen from Commander Scott that his gun and the other guns with which it has been compared have not been tried with shells. Commander Scott was, I think, present; if not, he must be very well cognisant of the fact that every one of these guns has been tried with shells—some shells loaded with sand, and some shells loaded with gunpowder. He is also probably aware that out of the shells that were tried, the whole of the shells on one system of rifling, which I need not name, split from the excessive strain thrown upon them; and the whole of the shells on other systems, among which I am glad to say his is one, did not split, and are serviceable, and some of them were fired a second time; therefore, that has been a most unaccountable mistake on the part of Commander Scott. The next thing was with regard to round shot. I think any gentleman would be left under the impression that no round shot had been fired from those guns. Very far from that, the guns being nearly of 42-pr. calibre, round shot of a special gauge were made for them, weighing 43 lbs. 6 ozs., and have been fired with two charges, 20 lb. and 12 lb. The 20 lb. charge is nearly half the weight of the shot. It gave enormous velocity. I think it gave a velocity of 2,100 feet. Such a velocity is extremely unprofitable, inasmuch as it is lost. It is absorbed by the resistance of the air in a very short space of time indeed. Then I turn to that drawing before you, in which Commander Scott has drawn an unfavourable comparison with respect to the French groove. I do not deny that Commander Scott advocates a groove which is less deep, and cuts much less into the gun; but I say a diagram of that kind is apt to give an erroneous impression, because you see the depth of the groove, but you do not see the thickness of the cylinder into which that groove is cut. However, I am not standing here to defend the French groove; on the contrary, I think the French groove is made unnecessarily deep. I now turn to the more agreeable point of referring to what we must all have learned with pleasure from the lecture of Major Owen—the substantial progress that has been made in the last four or five years in the making of the guns in our service. I apprehend that the Officers present here are not the advocates of this system or of that system; but their sincere and earnest desire is that the British Army and the British Navy should be in possession of the best, the most effective, the most simple, and least complicated and least costly gun that the mechanical skill of the country can supply. To produce that gun is the great object of those who are concerned in these questions, an object which is pursued under extraordinary difficulty, from the energy and self-assertion with which antagonistic principles and opinions are enforced in this place and in other places. But what we have learned from Major Owen, and what I can corroborate from my own testimony, is that, first, as regards the making of coil guns, to so great a degree of perfection has the coiling been brought by the better selection of iron, by a more skilful treatment of it, by that experience which is acquired in the lapse of time, that I saw a gun cut open the other day, and the closest examination could not detect the slightest joining or welding, or any other imperfection; and in some of the examinations which we have made lately, it has been necessary to apply strong acids, in order to ascertain the fact whether the gun had been coiled or not. That is surely a point on which we may all congratulate ourselves. Another point on which Major Owen touched, was that of a very skilful suggestion of Mr. Anderson, to hook the coils together, to prevent lateral displacement. There can be no question that when Sir William Armstrong first began to make his coil-guns, he trusted too much to the strength of the simple weld. We know the force of a weld is only one-half of the force of the metal in another direction, and the separate coils were butted against one another, without making them unite. We have now for a considerable time hooked the coils together, and they are consequently stronger. The next great point on which we may congratulate ourselves, and in which we are a-head of every power in Europe and America, is in the simplification lately introduced by Mr. Fraser, who by an

ingenious extension of the same principle, and by the selection of iron of different quality, has improved and cheapened the process of manufacture. Iron is the most protean substance in the world. Most of us will admit that five years ago we knew nothing about it; and we have all had to learn its qualities by costly, laborious, tentative processes, in which the great difficulty was first to ascertain the results, and then to draw correct conclusions from them. The result has been that guns are now produced, as Major Owen told us, at a cost of one-third, or at all events less than one-half of what they were produced for originally, and they are no doubt much better guns. So much, then, for the structure of the gun. Next, as to the question of round shot, whether we should primarily contemplate that state of things which naval men, full of the glories of their service in past times, are prone to talk about, as yard-arm to yard-arm engagements, but which I, as a landsman, firmly believe to be a myth. There is no doubt nobody questions that within a short distance, say 50 yards or 100 hundred yards, the frightful velocity of—2,100 feet if you like—which can be got up with a round shot of steel, gives it an overwhelming penetrating power which nothing can resist. But that velocity is resisted by a spring, by the atmosphere itself which is a spring, and it is absorbed with extraordinary rapidity. For example, to take the ten and-a-half inch smooth bore in the service, if you fire that gun with round shot, with a charge of 45 lb. or 50 lb. R. powder, that shot loses at about 480 yards, if my memory is correct, the penetrative power which the same gun rifled and firing elongated shot, with a charge reduced in the same proportion, or if not absolutely in the same proportion, reduced from 45 lb. to 35 lb., carries about 300 yards further. I think there is strong reason why we should prefer that our guns should be rifled, and should fire elongated shot, because they carry their velocity with them; rather than that you should put in those destructive charges which have this mechanical effect—they develop heat and flame, which disintegrate the mechanical structure of the gun. No matter whether the resistance in front of it is less or more, the mechanical structure of the gun is disintegrated by the heat of these great charges. It is not the strength of these guns that is in doubt, it is their endurance. We have never yet had an instance of failure of guns connected with the insufficient strength of the coiling. We have had the breech-pieces blow out in two cases; but the coils of these guns, the parts which surround the chamber have always resisted, and I believe they always will resist. But what we do find is that the powder searches out and eats into the imperfect welds of the iron, the silicates, and other foreign matters, and produces a state of things which, though it is not dangerous—for that is quite proved—is undoubtedly alarming, and may very reasonably justify the uneasiness which Officers, only accustomed to the smooth-bore guns, and the different material of former days, feel when they find these fissures and cracks presenting themselves. One can only hope that experience and progress will teach Officers that there is less danger to be apprehended from these things than they suppose. My desire has been in these few remarks to lead those Officers present, whose only wish is to receive information as to the real position of the Artillery question, to feel that it is not in that state of either neglect or—were I not humbly concerned myself I would add—of incompetence, which it has been so much the object of certain gentlemen to represent; that we are making guns far exceeding in power those possessed by any power in Europe or America; that those guns are put to proofs far exceeding anything that any other country ventures to put its guns to. The American Parrott 300-pounder gun, for example, is used with only 25 lbs. charge; the American 15-inch gun, which is the counterpart in weight of the Armstrong 600-pounder gun, is used with 35 lb. of powder; whereas we use 90 lb. of powder with round shot, and 70 lbs. with elongated shot. The same comparison holds good in many other instances. Other Powers use small charges; for the most part their charge is one-tenth or one-twelfth, ours is one-fourth or one-fifth. A few years ago we did not know how to make large guns; we are now learning to do it. For Heaven's sake do have a little patience, and a little faith in those who may be called upon by competent authorities to advise, to report, and to inquire into these matters. If you have good reason to think that they are incompetent, affected by personal partialities in any way, unfit for their duties, performing them in a manner which is not satisfactory, remove them, and put men whom you can trust into their

places. But do not abolish their offices, or run away with the notion that its duties can be performed by irresponsible and often interested advisers. Their office is an indispensable one, as indispensable as that of the Lord Chancellor himself.

Commander SCOTT: Will you allow me to ask one question, whether it is not the fact that the whole of the shells that were fired in my presence were filled with sand, and therefore were no more shells than that shot on the table?

General LEFROY: That is a new definition of a shell, but I believe Captain Scott is strictly correct, that the shells fired in his presence were filled with sand. Now, I will ask him, whether he is not aware that the same shells having been recovered, were fired afterwards filled with gunpowder?*

Captain SCOTT: Will you allow me to reply? Five shells only of my 50 shells which were recovered off the range were washed out, and fired against five French shells which were new, and five of Sir William Armstrong's shells also new. That is all the competitive shell firing there has been; and that was not in my presence. So I believe I am strictly correct in saying that there has been no shell firing at Shoeburyness, nor has there been quick firing. The 7-inch competitive guns I am speaking of.

Rear-Admiral Sir FREDERICK W. E. NICOLSON, Bart., C.B.: I do not rise to prolong the discussion on the subject which has been brought before us; but as a member of the Council of this Institution, I wish to express my great gratification, and I am sure you all cordially join in it, that at last we have heard from a member of the Ordnance Select Committee, a most competent authority, facts which will be recorded in the *Journal* of our Institution, and which will be read with interest by everybody who has the slightest acquaintance with these matters. It is so rarely that any person in an official position rises here to take part in our discussions, that I for one am highly delighted to find that my friend General Lefroy has on this occasion broken through that official reserve which I think is, generally speaking, too rigidly maintained, and has given us the advantage of his great knowledge, by the clear, and I may say, eloquent statement which he has made.

Major-General BOILEAU, R.E., F.R.S.: I would wish to ask one question of Major Owen, who has been so kind as to give us a most interesting paper on the construction of guns, whether the question of the external forms of the gun in reference to its longitudinal section has been made the subject of investigation and experiment. Everybody must observe in the models lying on the table, that in the form of the American Parrott gun, and of the others which have more or less similarity, there is a very marked difference; that after the gas has passed the reinforcement or breech of the Parrott gun, there is comparatively a very small amount of strength throughout the whole of the rest of the gun. The chase, I think it is called. But in these guns there appears to have been more attention paid to the relative power of the gas, as it extends along the bore. The Blakeley gun, as it appears to me, approaches more nearly than others to the form which the exterior of the gun ought to possess, to be in the same condition of resistance in respect of the tension and force of the gas at the different portions of the bore along which it passes. Of course I do not mean to say that there is or can be an exact relation between the tension of the gas and the resistance of the gun; but it has occurred to me to ask, especially as I remark so great a distinction between the external form of the Parrott gun and Blakeley gun, whether the subject of the exterior shape of the gun, with respect to longitudinal section, has formed the subject of investigation with the Select Committee, and if so, whether any specific conclusions have been arrived at? My own experience, which is confined chiefly to small bore shooting (and I may be permitted to say that the principle applies to large guns), has satisfied me that rifled barrels

* *Remarks subsequently communicated by Brigadier-General Lefroy.*—Officers unacquainted with Shoeburyness may require to be informed that there are stringent orders applying to the firing of shells filled with powder, whether fuzed or not; local circumstances require precautions to be taken which are not necessary with shells filled with sand, and which would be very inconvenient if enforced on every occasion of practice. It it consequently customary to fill the shells with sand.—J. H. L.

shoot better in which the barrel is nearly as thick at the muzzle as at the breech. I have one rifle which has nearly the same thickness at the muzzle as at the breech, and it shoots so remarkably well, that I call it "Bull's-eye Jack." The other rifles, which are not so thick at the muzzle, appear to go off with a twang, which must give the shot an inaccurate direction. Those of the Armstrong guns which I have seen at Woolwich appear to me to have that one defect, that the part before the trunnions was exceedingly slender, as compared with the other part, and was liable in delivering its shot to give a vibratory motion, which would alter its direction to a certain extent.

Commander ARTHUR, R.N.: There is one point which Major Owen stated on his own authority; therefore, I do not hesitate to differ from him. It is in reference to the effect which constant firing will have on the plates. I deny totally that any plates that will bear the fire of three shots near one spot will not bear the same test on the whole surface. It is the bolts that give way. To take it for granted that the plates will give way before the bolts do under these circumstances would be leading ourselves astray, and drawing our conclusions from an error. The bolts are the points to which we should draw our attention. There is also another point. I think we are rather liable to error as regards initial velocity. I think, if the point is clearly considered, you will find that the initial velocity will bear direct relation between the charge of powder and shot, if the friction of rifled shot is taken into consideration. Of course, there are some cases in which a gun firing a rifled shot is also used for smooth-bore shot. In that case there will be a large proportion of powder wasted by want of length of barrel, and by escape in the grooves; in fact, the powder cannot be burned. This is a thing, of course, that will have to be determined in the guns which are used. Where you try to construct one gun for two purposes you will always find that you will fail partly in one of them. (I merely make these remarks, wishing that there may not be any error.)

Captain SELWYN, R.N.: Will the meeting allow me to say one or two words with regard to points that have not been touched upon by the lecturer? First, with regard to the use of steel for guns. I think I understood the lecturer to acknowledge, as has been acknowledged in this theatre over and over again, that to steel we look for the best effects. I should like to ask to what extent experiments have been carried in this country with the view to realize the predictions on metal which promises us the best results? Has not very much more labour been expended in trying to perfect that which is acknowledged to be an inferior metal, instead of trying some experiments on a large scale on the stronger metal? We have arrived at the use of steel for the interior of our guns. The question is, cannot we carry the use of that metal further? And on what does the advantage which we have gained depend? I take it that the condition to be desired in the interior of a gun is extreme hardness. The Americans have obtained that in a very large measure by chilling the casting, by pumping water through the gun while it is cooling in the core. We have used steel tubes. In both cases success has been gained to a certain extent in producing a good gun. We have got the hard interior surface; but we have not considered as yet how far we might by coincident slow cooling of the outside, artificial slow cooling, produce that peculiar arrangement of tension of the metal, which might give us better results than we have yet had. I think experiments might be usefully tried in that direction. The thickness of guns at the breech, to which the lecturer also adverted, seems to me to be also very ill understood. In this gun which you see before you, you have an arrangement which certainly gives points of weakness and points of strength, but by no means are those points arranged with reference to the tension inside the gun. The American guns are made very much with that view. They follow the curves which one would naturally expect outside, to follow the curves of tension inside. I confess I could not follow the lecturer into his view of the subject when he said the diameter of the bore and the twist of the rifling did not influence the tension on the gun. First of all, we must consider that the increased diameter of the bore infers a much greater increase in the weight of shot, and that that shot is always reposing on the lower side of the bore until it goes out of the gun. In every system it so reposes on the bottom of the bore, except in the centrical or wedge system of Captain Scott, which brings the shot up into the

centre of the bore. It is perfectly clear that if we increase the twist up to a given point it tends to burst the gun, so that there is a point evidently at which the twist does very materially influence the tension on the gun. Now, where is the point at which it does not influence at all? It is very remarkable too that although we are told most eloquently by General Lefroy that we have done better than other powers, we are told by the lecturer that the French gun gives about the worst practice that he ever saw, so bad that he could not make head or tail of it.

Major OWEN: I did not say anything of the kind. Perhaps I spoke very indistinctly. I have no doubt you understood me to say that. I did not say it was the worst practice I ever saw. I said that, judging from their published results, the practice from one particular gun, the *canon de* 12, is exceedingly bad.* I am sure, if you look at the tables, you will find that what I state is the case.

Captain SELWYN: I think it is only a question of degree. However, it is certainly not the commendable gun one would imagine from the effect produced, yet, it is now brought forward as the system which is to supersede all those of which we have previously heard. It is the gun of the day. It is a gun which has none of the advantages of being able to fire round shot without injury to the grooves; none of the advantages of the centrical system at all, or only in a small measure obtained lately by giving a peculiar form to the studs, which has had the result of doing to a certain extent what Captain Scott does perfectly, and has so far materially improved the firing of the French gun. The studs are turned to a peculiar surface, and they do act to a certain extent as wedges, and centre the shot to a certain extent.

Major PALLISER: That I deny; they do not centre it in the least.

Captain SELWYN: General Lefroy also said that the rifled gun had fired a 35 lb. charge, and that the guns we are now using carry frightful charges of powder. I think we shall all recollect that in the Dardanelles we have seen guns that have fired much larger charges than those we are talking of now—stone shot, it is true, and very large charges. I think Baron de Tott fired a 200 lb. shot out of one of these guns, and was not much frightened at it. I distrust and dislike apology for little holes made in the gun. First, we are told that hoops were invented; then that the coils were perfect; then that they required hooks. The coils do not appear to me to be hooked together. The different portions of the gun are hooked together, but the welds of the coils are not a bit more hooked together than they were before. I must also take great exception to what General Lefroy said with regard to the myths of the naval profession generally. He may depend upon it when a gentleman, with the experience and means of Admiral Sartorius, gets up and merely expresses the general opinion of naval men in saying that no action was ever or will be, decided at long range, an Artillery Officer must not qualify these as myths. We do know what we are about at sea. I do not think we shall ever undervalue the high velocity which we seek for in advocating the use of the round ball. We know what we want, and we would only ask our artillery friends to concede to us the belief that we are not attacking their guns, but we are simply asking for as good a weapon as we think we can get, and, I think I may say more, which we shall get, with the united talents of Armstrong, Anderson, and Fraser; and I hope by and bye Captain Scott will be considered, and that his gun will have a thoroughly fair trial, which it never has had yet, and not a trial by some one in their own way for their own purposes.

Major PALLISER: I felt called upon to take exception to your remark about that shot being centred. You said it was a matter between me and Captain Scott. I have seen repeatedly in the papers that the good shooting of that gun was due to the shot being centred on Captain Scott's principle. I have seen it stated in the *Army and Navy Gazette*, the *Engineer*, and in other papers. I did not think it worth while to contradict or take any notice of these statements; but when I hear Captain Selwyn deliberately state here that it is the centring principle that has made that gun shoot so well, I think I am justified in expressing my dissent from it. I have examined a great number of the shot which have been fired, and have found inva-

* The grooves, the twist, and the studs in this system are different to those in the so erroneously termed French or Palliser system of rifling.—C. H. O.

riably, a "step" on the driving edge of one row of studs in each shot. As you have already stated, the shot lies in the bottom of the bore by the action of gravity, and when the gun is fired, the pressure of the fired gunpowder, passing over the upper part of the shot, holds it firmly down. The theory of rounded grooves, and of correspondingly rounded studs, whereby the driving pressure of the grooves lifts the shot into centre, will not bear examination. What is actually the case is this: the studs shear at the first starting, and the upper stud over-rides its groove, and thus a portion of it, which I have termed a "step," projects between the bore of the gun and the body of the shot, and thereby prevents the shot from rising towards the centre. You will find there is a step or projection ·08 of an inch high on the studs on one side of that shot, and that the studs on the other side are shorn quite level with the body of the shot; therefore, as these shot never did rise into centre, I do not think it can be said "that the good shooting of that gun is due to the centring system." There is another point I wish to notice. I think somebody remarked that round shot and elongated shot have not been tried under similar circumstances. Now, would round steel shot, weighing 105 lbs., fired with 25 lbs. of powder out of a 9-inch smooth-bore gun, be considered a fair comparison with an elongated steel, or chilled shot, weighing about 100 lbs., fired with 25 lbs. of powder from a 7-inch rifled gun?

Captain FISHBOURNE: Certainly not; the tension on the gun would not be equal in each case.

Major PALLISER: The same weight of shot and the same weight of powder?

Captain FISHBOURNE: That is not the question. The question is to get the greatest results from a given gun. You take your gun and get the greatest results from it; I will take my gun and get the greatest results from that, the strength of the gun being the limitation.

Major PALLISER: You do not think the same weight of powder and the same weight of shot a fair criterion?

Captain FISHBOURNE: Certainly not.

Major PALLISER: Then I have nothing further to add.

The CHAIRMAN: If no other gentleman has any remark to make, perhaps Major Owen would wish to reply.

Major OWEN: Captain Fishbourne misunderstood me as to the gaining twist. I did not say that by employing the gaining twist the whole gun was relieved from strain. I said it was relieved from a certain amount of initial strain (the strain at starting), which is usually the strain that causes the damage.

Captain FISHBOURNE: I did not mean to represent you as saying that.

Major OWEN: As to what Captain Scott said about the Horsfall gun. I am quite aware that the shot used by Mr. Whitworth was steel, and that the shot out of the Horsfall gun was cast-iron. I do not give that example to show particularly the effect of an elongated shot, but to show that Mr. Whitworth, by skilfully employing the elongated form, and also a better material, produced those effects. Captain Selwyn remarked that the bores were chilled to obtain hardness. I never understood it in that way. I believe the bores of guns in America are chilled in order to render uniform the contraction throughout the mass, so that the different portions of the metal should be in a state of equilibrium. I do not believe it is the case at all, that the Americans chill their bores for hardness, cast-iron being sufficiently hard without chilling, but to render uniform the contraction. Captain Selwyn also, I think, rather misunderstood what I said about the twist, and about the diameter of the bore. I did not say that they had no effect on the strain: I said they were no part of the system of rifling. On the contrary, I said the twist increased the strain, and I pointed out that by employing the gaining twist, the strain was decreased. If the twist did not affect it at all, why did the gaining twist decrease the strain? There is another point. I think General Boileau alluded to some experiments with reference to the exterior of the gun. I am not aware of any experiments, except what the Americans made several years ago, by firing bullets at different portions of the gun —the Dahlgren experiments. Some Officers may know of other experiments. I am not aware of any.